New Scientist

WEEKLY 31 December 2022

PREVIEW OF 2023

Saving the Amazon
Europe gets tough on AI
The next covid vaccines
Ultimate X-ray machine
Can we crack consciousness?
Exploring Jupiter's moons
Books to look forward to

Lost GIANT

The hunt for the largest animal that ever existed

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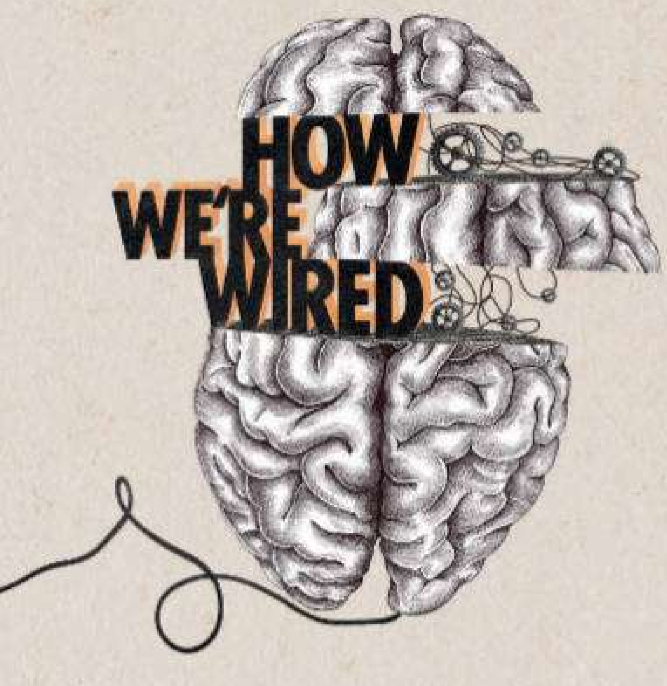

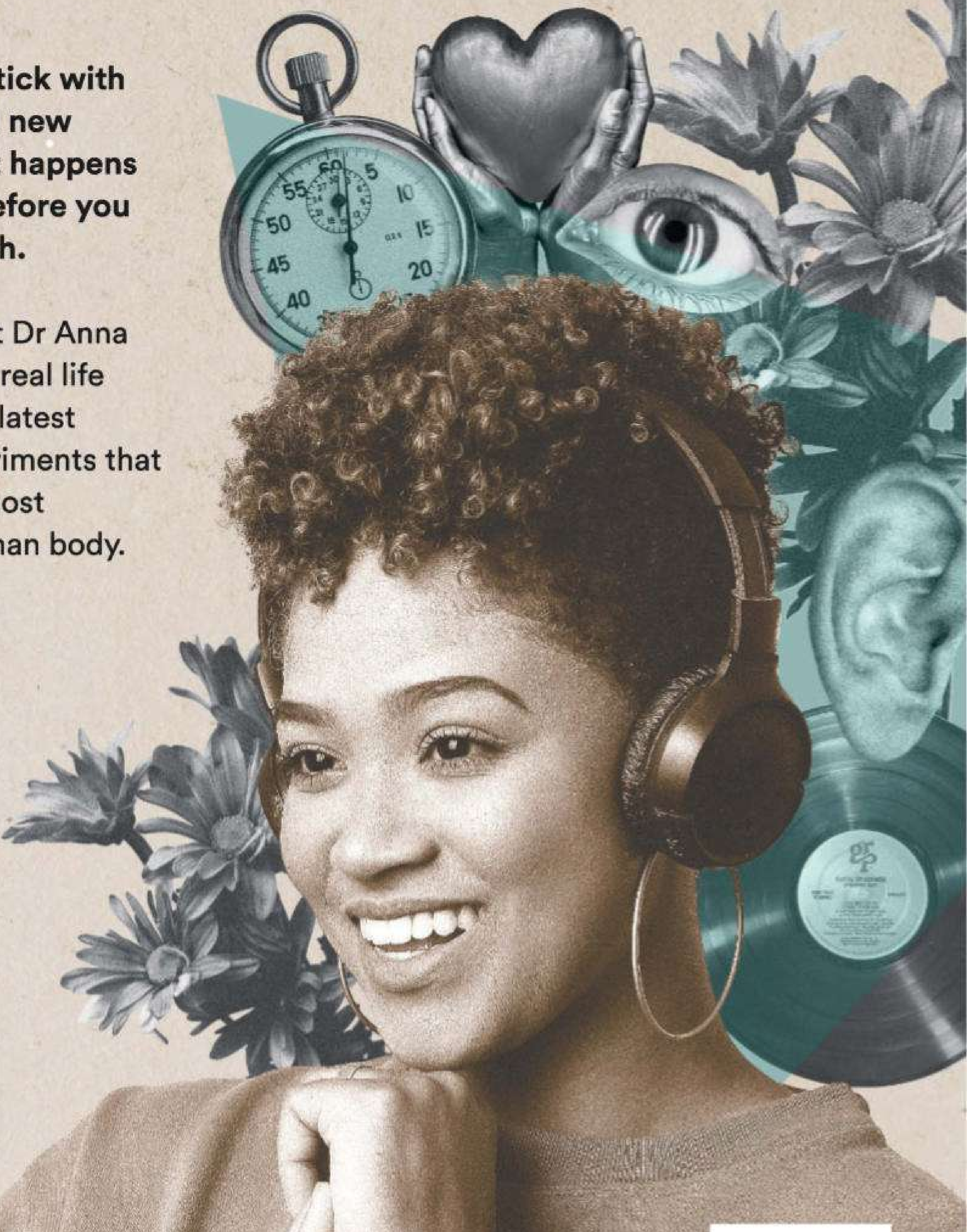

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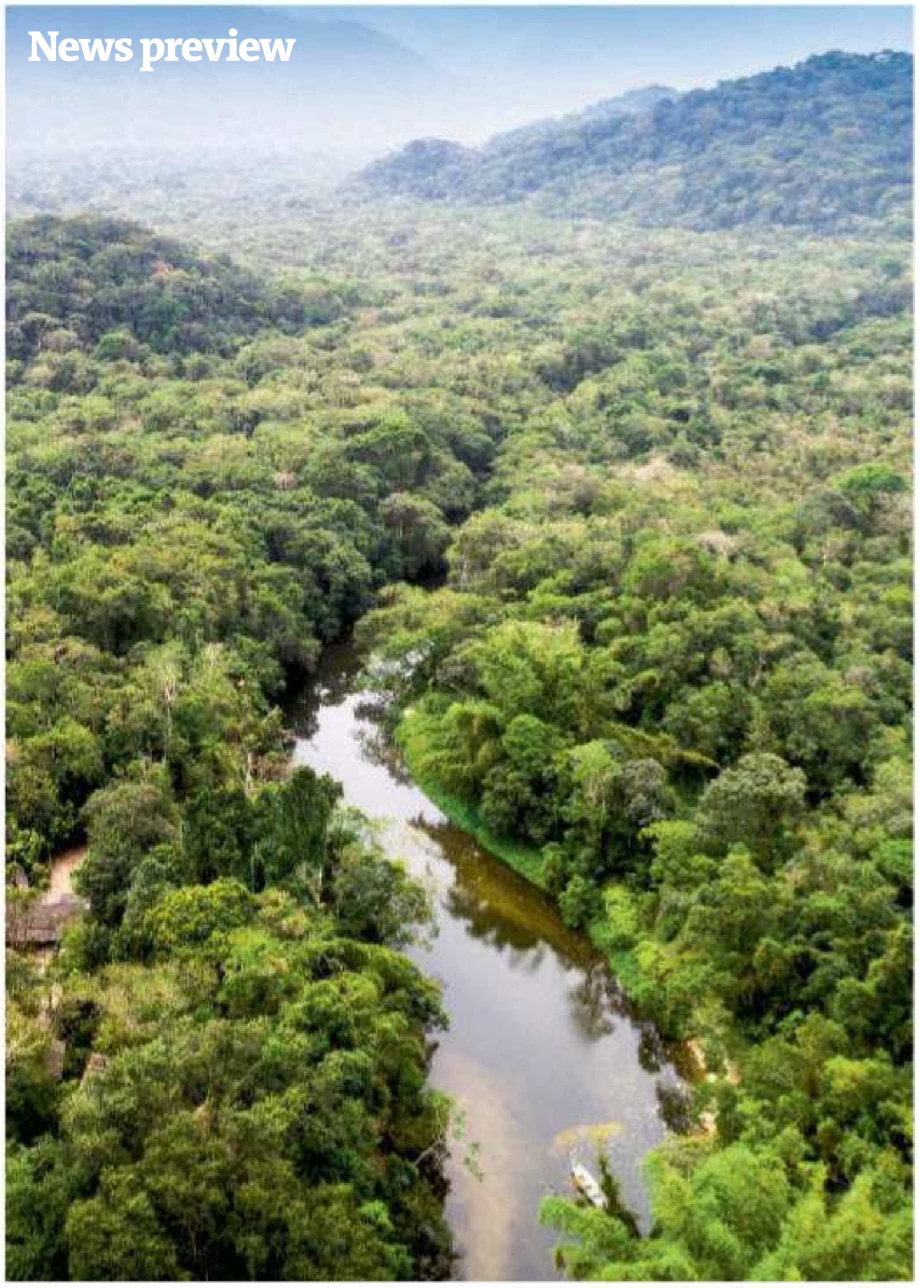

GUSTAVO FRAZAO/SHUTTERSTOCK

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Virtual event

Wonders of the Ice: Science on top of the world

The Arctic is a harsh yet beautiful region that has fascinated scientists for centuries. Join *New Scientist*'s Rowan Hooper for this free talk on the region's wildlife and how humans could refreeze areas in the Arctic circle. We will also hear from glaciologist Ulyana Horodyskyj Pena about working in an extreme environment. On 12 January 2023 at 8pm GMT/3pm EST and on demand.

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Podcast

Holiday episode

This week, magazine editor Catherine de Lange and head of features Daniel Cossins sit down to discuss their favourite features of 2022, including the longevity diet that could add years to your life and the blips in the Large Hadron Collider that might herald a new era of physics.

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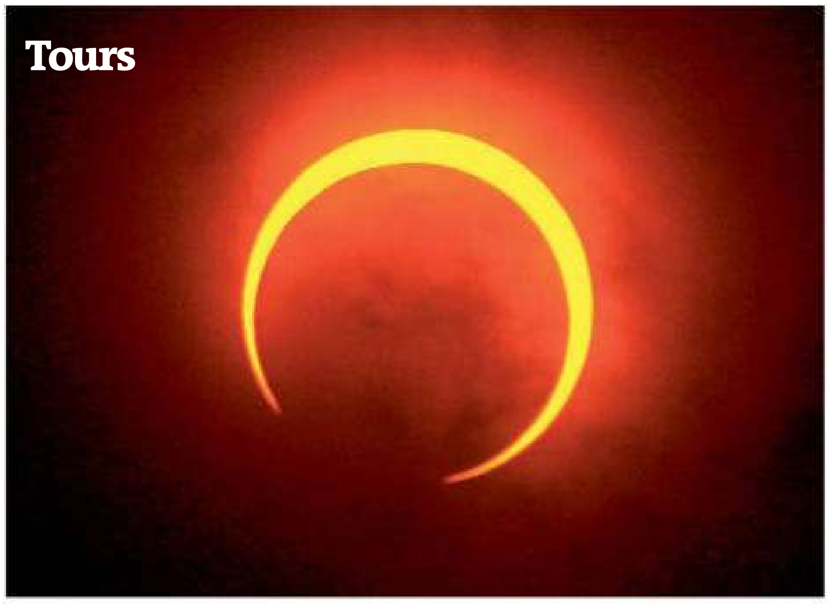


BEAWIHARTA BEAWIHARTA/REUTERS/ALAMY

Total eclipse Witness this celestial wonder on an Indonesian beach

GIEDRIUS STAKAUSKAS/EYEEM/ALAMY

Frozen wonderland Discover the spectacular wildlife of the Arctic

Video

Hangover help

Many of us have been there: one drink turns into two and then too many, and no matter which folklore remedy we adhere to, a hangover is often just around the corner. We have dug out this episode of Science with Sam from our archive to explain why we get hangovers, why some people suffer worse than others and what, if anything, can be done to cure one.

youtube.com/newscientist

Newsletter

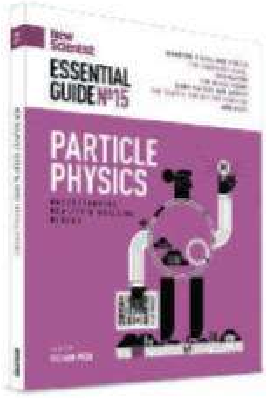
Health Check

In this month's newsletter, reporter Clare Wilson chooses her seven favourite medical stories of the year. Find out more about a drug that delays type 1 diabetes, covid-19's trajectory, pig heart transplants and a new amyloid treatment for Alzheimer's that has been approved in the US.

newscientist.com/health-check

Video

> **"Between 5 and 23 per cent of people are reported to be hangover resistant"**



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A year of promise

In 2023, opportunities to build a better future for humanity abound

EVERY year feels like a new beginning, but, as we explore in this issue, many events set for 2023 feel like opportunities for humanity to choose a more hopeful future.

Even the first day of the year will see a key turning point, with Luiz Inácio Lula da Silva taking office as president of Brazil. He replaces Jair Bolsonaro, who, for the past four years, has overseen destruction of the Amazon rainforest at a pace not seen in decades. Lula has promised to halt and reverse this devastation, and political leaders elsewhere increasingly understand the need to preserve trees (see page 8). We will all benefit from a protected Amazon.

Across the Atlantic Ocean, the European Union will also make a global impact. The bloc's Artificial Intelligence Act, which will be debated and drafted throughout 2023, is the world's first attempt to create broad standards for the use of AI (see page 9). While these would only legally apply in its 27 member states, the EU has a track record of inspiring global tech regulations, as giant firms like Meta find it easier to apply a one-size-fits-all model to their customers.

> "There will always be doom and gloom in the world, but there is a lot to look forward to this year"

Even our diets are set to shift in 2023. The poultry industry is wrestling with the impacts of the avian flu crisis, which has effectively made it impossible to produce free-range eggs or chickens in many places (see page 20). The role the industry plays in causing or exacerbating avian pandemics that threaten birds shouldn't be ignored either. At the same time, the first commercial factory for turning energy directly into food is due to launch in Finland, in a move that could massively cut the environmental impact of farming, if scaled up (see page 16). Whether consumers will accept the transition from traditional food production to high-tech methods in an effort to save Earth remains to be seen.

All of that is without mentioning the new spacecraft set to visit moons, both ours (see page 7) and Jupiter's (see page 18), continued research into covid-19 vaccines (see page 11) and even efforts to understand the very nature of consciousness (see page 14). Yes, there will always be doom and gloom in the world, but there is a lot to look forward to this year. ▮

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SPACEX

1

Space exploration

THE largest rocket ever seen, at a towering 120 metres tall, will soon blast into orbit. SpaceX's unique iterative design process means it has already tested several prototypes of its Starship vehicle, resulting in three successful "hops" of up to 10 kilometres in altitude, as well as four malfunctions.

The first orbital test flight of Starship was planned for no earlier than December 2022, but as *New Scientist* went to press, it hadn't yet taken place and it was likely to be delayed until early 2023.

If all goes well, its first crewed flight will also take place in 2023, carrying crew members and space tourists into orbit. A second crewed flight in 2023 aims to take tourists on a wide loop around the moon.

Leah Crane

Environment

A turning point for the Amazon

New political leaders in Brazil and Colombia have promised to protect the rainforest, raising hopes of saving the ecosystem from becoming savannah, says **Luke Taylor**

The Potaro river running through the Amazon rainforest in Guyana

PATRICK FORT/AFP VIA GETTY IMAGES

2

AFTER four years of runaway deforestation in the Amazon under Brazilian president Jair Bolsonaro, the election of Luiz Inácio Lula da Silva, who takes office on 1 January, could be a decisive turning point.

Lula has pledged to aim for net-zero deforestation – the first Brazilian president to do so. "A standing tree is worth more than thousands of logs," he said in his victory speech on 31 October. "That is why we will resume the surveillance of the entire Amazon and any illegal activity."

As well as the restoration of monitoring and surveillance efforts, Lula is proposing several ambitious projects, such as a national climate authority and a sustainable farming scheme. But without a majority in Brazil's Congress, it is unclear whether he will be able to deliver on these pledges. It will also take time to dislodge the illegal industries that have taken hold in the Amazon, such as gold mining.

Despite the challenges ahead, Lula's win has made researchers and conservationists more optimistic that the Amazon could be saved, even as there are signs it is hitting a tipping point that would see it transform into savannah. "The election of Lula is a great reason for hope," says Mark Plotkin, an ethnobotanist and co-founder of non-profit organisation the Amazon Conservation Team.

> "We've been waiting for a long time for political will to implement change and I think we will finally get it"

The impact of Lula's environmental policy should be magnified by the recent election of eco-conscious governments elsewhere in South America that have campaigned to protect the rainforest.

In Colombia, which is home to some of the Amazon's most biodiverse regions, President Gustavo Petro is also positioning himself as a regional steward of the rainforest, after taking office in August 2022. Petro is pushing for high-income countries to support South America's defence of the rainforest and he is also overseeing a total rethink of Colombia's conservation strategy.

After decades of criminalising farmers who clear the forest for agriculture, the Colombian government now plans to offer them financial support to transition to more sustainable practices, such as harvesting Amazonian fruits from the trees.

The country's environment minister also proposes diverting all carbon tax revenue directly to conservation schemes and forging an "Amazon Bloc" with other South American nations, so that they will have more leverage to secure international funds.

With Petro, Lula and US president Joe Biden all having been elected after campaigning to protect the Amazon, researchers say they have the political and public support to move forward with plans to conserve and restore the rainforest.

There may also be more opportunities for collaboration between different countries and groups. Bolsonaro blocked conservation in the wider region, not just Brazil, says Martín von

Hildebrand, founder of the non-profit organisation Gaia Amazonas. Alliances between NGOs, scientists and Indigenous peoples can now be strengthened and their plans enacted, he says.

Restoring the forest

This could be the year that decades of damage begin to be reversed, says von Hildebrand. The anthropologist is working with researchers and Indigenous communities to draw up a reforestation project that would create a wildlife corridor stretching from the Andes to the Atlantic Ocean. "We've been waiting for a long time for political will to implement change and I think we are finally going to get it," he says.

Carlos Nobre at the University of São Paulo, Brazil, believes that conservationists can capitalise on political support and the growing urgency of climate change to spur efforts towards reforestation.

At the COP27 climate summit in November 2022, Nobre presented a project to restore more than 1 million square kilometres of rainforest that would, he says, "store 1 billion tonnes of carbon dioxide a year for decades to come and prevent the Amazon from reaching a tipping point".

Though the Amazon's future remains uncertain, the importance of its conservation for climate change will only become more obvious in 2023, says von Hildebrand.

"It's not only a carbon sink and a haven of biodiversity, but with its flying rivers [currents of water vapour], it's a water pump for the entire Amazon, the Andes and beyond," he says. "The forest is absolutely necessary. If we lose the forest, we simply won't have water in this part of the world." ▮

Technology

3

Europe's AI regulations could lead the way for the world

Jeremy Hsu

THE European Union is set to create the world's first broad standards for regulating artificial intelligence. As well as determining how the technology affects the lives of almost 450 million citizens in the 27 countries of the EU, the rules are likely to influence how AI is used elsewhere in the world.

"The idea is that you have a harmonised system, which is really good," says Sandra Wachter at the University of Oxford.

The EU is working towards finalising the text of the Artificial Intelligence Act in 2023. Its focus is on AI systems that could detrimentally affect citizens. Some uses, such as government-run social scoring, could be banned. Others would be labelled as high risk and strictly regulated. This is likely to include systems involved in accessing essential services, such as loans or benefits, judicial systems and workplace hiring decisions. But most AI uses, such as chatbots that assist with orders for pizza in phone apps, aren't expected to be categorised as high risk.

The act would require all AI systems to notify people if they are interacting with a computer, not a person. "This could change how platforms like Facebook and TikTok look, since their content-recommendation algorithms should fall under this requirement," says Emmie Hine at the University of Bologna in Italy.

Although many policy experts and tech giants have welcomed the idea of regulation, there is no widespread agreement on how some applications of AI, such as facial recognition in public spaces, should be categorised.

Coming up with definitions that cover AI uses in many areas will also be tough. "That creates a really difficult scenario where you're trying to include fairly simple algorithms that are doing really important stuff, and exclude fairly technically complicated algorithms that are doing trivial stuff," says Alex Engler at the Brookings Institution in Washington DC.

Another outstanding issue is that law-makers must clarify how the act will be enforced, says Vanja Skoric at the European Center for Not-for-Profit Law in the Netherlands, who wants to see the final regulations adopt a "robust and independent EU AI board with concrete monitoring powers".

AIs used for national security or military purposes are likely to be excluded from the rules, says Skoric, despite an opinion poll suggesting that EU citizens are concerned about such uses.

Whatever the final AI Act looks like, compliance will be mandatory for any company delivering AI-powered services to people in the EU. Some platforms with an international customer base may adopt the AI Act standards for all users, whereas those with more isolated and localised algorithms may not, says Engler.

The AI Act could lead to similar regulations worldwide, says Hine. Countries such as Brazil and Canada have already adopted parts of the draft act in their own proposals. "Almost every part of the world is agreeing that we need to do something," says Wachter. ▮

"This could change how platforms like Facebook and TikTok look"

Margrethe Vestager coordinates EU strategy on artificial intelligence

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4

Coronavirus

The next covid-19 vaccines

Global vaccine inequality, waning immunity and evolving variants mean jabs are still needed, but new ones are unlikely in 2023, says **Michael Le Page**

THANKS to vaccines, many countries have ended protective measures against covid-19 without a large increase in deaths. Nevertheless, just under one-third of people globally hadn't received a single dose of covid-19 vaccine as of mid-December 2022, according to Our World in Data. Plus, immunity is waning and the SARS-CoV-2 coronavirus is evolving to dodge our immune systems.

We will therefore need new and improved covid-19 vaccines for many years to come. What can we expect in 2023? The disappointing answer is we will probably have the same vaccines, but fewer doses.

According to UK science analytics company Airfinity, the number of covid-19 vaccine doses sold globally fell from 5.7 billion in 2021 to 3 billion in 2022 – and will fall further to 1.6 billion doses in 2023, probably because countries think the pandemic is less urgent.

These figures don't include nations producing their own vaccines, such as China, which hopes to ramp up its efforts. At the end of November 2022, China announced plans to vaccinate more of its older population. According to China's National Health Commission, 40 per cent of people aged over 80 in the country had received three covid-19 vaccine doses in November, up from about 20 per cent in April.

Outside China, the mRNA vaccines produced by Pfizer/BioNTech and Moderna are likely to continue to dominate sales. Their latest vaccines code for the outer spike proteins of the original virus and two omicron subvariants.

"There is a possibility that the vaccines are updated again and, if that were the case, we'd expect it to be for the following booster campaign in autumn/winter next year," says Matt Linley at Airfinity. "But this depends on how the variants evolve over time."

"Approval for any new covid-19 vaccine is harder, as they need to be better than the ones we have"

There are 50 approved covid-19 vaccines, according to records compiled by McGill University in Montreal, Canada, though many are approved in just one country. Another 250 vaccine candidates are being tested in 80 countries.

Many of these candidates are similar to existing vaccines, but some groups are trying to develop vaccines that are better than the ones we already have.

One approach is to provide broad protection against a range of potential variants, making it harder for the virus to evolve to dodge vaccine-induced immunity. Pfizer is testing an mRNA vaccine designed to provoke a response by T-cells of the immune system against several coronavirus proteins, not just an antibody response against the spike protein. T-cells often provide longer protection than antibodies. Several of these vaccines are in development, but it is unlikely that any will be approved in 2023.

The second approach is to create vaccines that provide much better protection against infection and transmission by inducing so-called mucosal immunity.

The mucous membranes of our nose, throat and lungs are where infections typically start and where the viruses that go on to infect people are produced. The hope is that delivering vaccines directly to these membranes – such as via the nose – will stimulate a strong response.

Four nasal vaccines have been approved in China, India, Iran and Russia. There is little information on the last two, but India's iNCOVACC and China's Convidecia Air were approved on the basis that, when given as a booster, they produce levels of antibodies that are at least as high as those from an injected booster.

Sandy Douglas at the University of Oxford and his colleagues tested a nasal spray vaccine earlier in 2022, with disappointing results. As this was very similar to iNCOVACC, the team is trying to figure out why the candidate didn't work as well, he says.

No nasal vaccines are likely to be approved soon in Europe or North America, says Douglas. Regulators will want to be sure they are safe and don't cause an inflammatory response, for instance in those with asthma. Getting approval for any new vaccine is becoming harder, as they must be better than the ones we have, he says.

The need for new vaccines is also less urgent now, so candidates will follow the standard, longer time frames for approval, says Linley.

Overall, there is a way to go before we have a covid-19 vaccine that gives robust protection against infection, transmission and new variants, but we mustn't take our eye off this goal, says Douglas. "This is important not just for this pandemic, but to put us in a better position next time there's a [new infectious] outbreak. ▮

People queuing to be vaccinated in Taipei, Taiwan, in April 2022

SAM YEH/AFP VIA GETTY IMAGES

5

The electron gun that powers the Linac Coherent Light Source-II X-ray laser

MARILYN CHUNG/LAWRENCE BERKELEY

Particle physics

Getting ready to fire up the world's ultimate X-ray machine

Karmela Padavic-Callaghan

EARLY in 2023, electrons flying at nearly the speed of light in a tunnel beneath California will produce the brightest X-rays ever seen on Earth, allowing us to examine atoms and molecules in unprecedented detail.

These record-breaking X-rays will be produced at the SLAC National Accelerator Laboratory, which has upgraded its Linac Coherent Light Source (LCLS) X-ray laser to be the fastest and brightest in the world. While the LCLS produced about 100 X-ray pulses each second, LCLS-II will increase that number to 1 million, with X-rays that are about 10,000 times brighter.

At the heart of the machine are electrons moving through a 3-kilometre-long metal tube. The SLAC researchers knock them out of a copper plate with ultraviolet light, then use devices that emit intense microwave pulses to push the electrons to near the speed of light.

Once up to speed, the electrons pass through thousands of magnets in rows a few millimetres apart that are arranged with alternating magnetic poles. These alternating poles wiggle electrons back and forth, producing X-rays in predictable, narrow pulses with controllable energies 1 million times every second. The pulses can be used to image inside materials, just like a medical X-ray, but 1 trillion trillion times brighter.

The upgrade was necessary as more powerful and frequent X-ray pulses make more informative images, says Mike Dunne at SLAC.

"It's like a super microscope. X-rays have a wavelength about the size of an atom, so you can image individual atoms within a molecule with high precision," he says. "We can see timescales on which atoms make friends with each other, on which chemical bonds are made or broken. It'll be like watching a movie of molecules evolving."

This will be useful for studies ranging from fundamental physics to designing solar panels and developing drugs, says Amy Cordones-Hahn, also at SLAC.

> "We can see timescales on which chemical bonds are made. It will be like watching a film of molecules evolving"

Key to the LCLS-II upgrade was refurbishing the tunnel that guides electrons through the magnets by switching the copper lining with a niobium one, cooled to about -271°C to make it a superconductor. Without this, the upgraded laser would have been so energetic that it would have melted the tunnel.

Researchers assembled about 700 metres of niobium pieces in labs across the US, then had to transport them to California before welding them together without any contamination or errors. They also had to arrange the magnets with exquisite precision, because even the smallest mistake in alignment would have been massively amplified by the fast-moving electrons. "LCLS-II is a miracle of engineering as well as science," says Dunne.

The team began sending electrons through the niobium tunnel in September 2022 and hopes to produce the first record-breaking X-rays in February or March 2023. "It will be a tool that will give us so much more information than we can get with other methods. I think everyone should want to come to experiment here," says Cordones-Hahn. ∎

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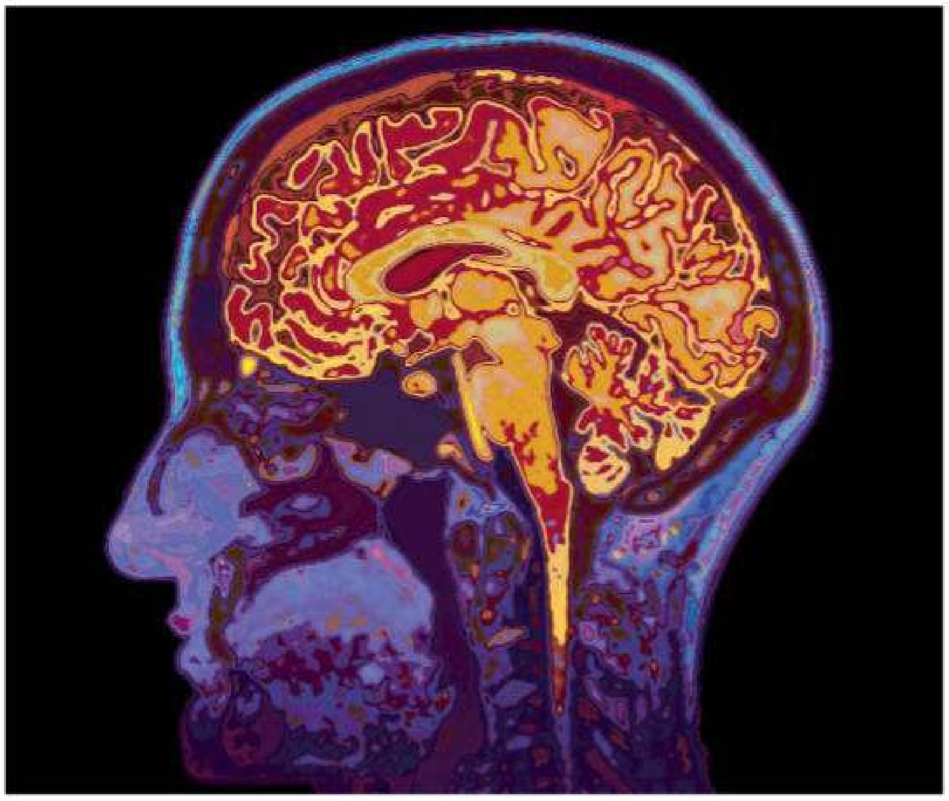
Neuroscience

Searching for the signature of you

A long-standing bet on the mystery of consciousness is set to be resolved in 2023, but many puzzles will remain, says **Jason Arunn Murugesu**

6



Neuroimaging studies could help us find signs of consciousness in the brain

SPEEDKINGZ/SHUTTERSTOCK

David Chalmers (top) and Christof Koch made a bet about consciousness

RAY ROCHIN/GETTY IMAGES

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WILL we ever be able to locate consciousness within the brain? It is a question that, a quarter of a century ago, two researchers aimed to settle with a wager that is due to expire in 2023.

In 1998, Christof Koch, now at the Allen Institute for Brain Science in Seattle, bet David Chalmers, now at New York University, that scientists would discover a specific signature – or neural correlate – of consciousness within 25 years.

"I was a young academic, I was at the world's best research university," says Koch. "I was inexperienced, I thought 'OK, we're going to nail this problem'." Now, he admits he has probably lost. "I'll bring David a good bottle of red wine," he says.

The bet's end will be marked at the Association of Scientific Studies of Consciousness conference in June 2023. Chalmers is coy when asked if he is confident in winning. "Miracles could happen in six months," he says.

Finding the neural correlates of consciousness could have medical applications, such as determining if someone in a coma is self-aware, and could also help illuminate deep philosophical questions. "Consciousness comes prior to physics, comes prior to science – the only way I experience the world is through consciousness," says Koch.

"If we understand consciousness, we'll understand ourselves a whole lot better," says Chalmers.

They are part of a team hoping to test two major theories of consciousness that developed in the years after their bet.

The first idea, called global workspace theory, suggests that the brain only produces a signal when you first become consciously aware of an object, and then the signal disappears. Under this theory, the brain processes non-conscious experiences in sensory areas, such as the visual cortex, and we only become aware of them if this information is then broadcast to a cluster of neurons distributed across the brain that integrate multiple senses into a single flash of perception. Brain regions that have dense links to others, such as the prefrontal or parietal areas, are prime candidates for these neurons, says Koch.

> "If we understand consciousness, we will understand ourselves a whole lot better"

The other idea, integrated information theory, argues that if you are aware of an object for a period of time, there must be a signal of consciousness for the same duration. The theory suggests that this signal will be discovered in the posterior cortex, as researchers have previously found that some neurons in this region are particularly active when measuring conscious perception.

One experiment the team is planning will involve participants playing a video game while having their brains scanned. The game will include random objects that may or may not be perceived by the player. Afterwards, the participants will report which of these stimuli they perceived, in the hope of identifying which parts of the brain are linked with conscious perception. If signals in these areas come and go, that would favour global workspace theory, while persistent signals would point at integrated information theory.

The results of the study will be published in 2023, but are unlikely to be the final word on the difficult problem of consciousness, says Koch. "The brain is by far the most complex piece of active matter in the known universe." ▮

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7

Biotechnology

Learning how to make green food from air and electricity

Michael Le Page

SOLAR FOODS

FARMING is devastating the planet. But there could be a much more environmentally friendly way to feed ourselves: using renewable energy to turn carbon dioxide into food.

"This is becoming a reality," says Pasi Vainikka at Solar Foods. The company is building the first commercial-scale factory, near Helsinki in Finland, that will be able to make food directly from CO_2. It will produce 100 tonnes per year, enough for 4 or 5 million meals, he says. "We are a bit behind schedule, but production may start just about in 2023," says Vainikka.

There can be no doubt about the need to find greener ways to grow food. Conventional agriculture – including organic farming – causes damage to the environment in many ways. It requires a lot of land, leading to habitat loss and deforestation, and often needs vast amounts of water, which can result in lakes and rivers drying up. It is also the source of a third of all greenhouse gas emissions and releases other pollutants, such as the nitrates that create dead zones in lakes and oceans.

It isn't very efficient, either. Crops typically convert less than 1 per cent of light energy into usable biomass. Feeding plants to animals to produce meat is less efficient still.

Instead, Solar Foods plans to bypass photosynthesis altogether, and grow bacteria that use hydrogen as their source of energy.

At the factory, renewable electricity will be used to split water to produce hydrogen and oxygen. The hydrogen will be added to large vats, where the bacteria grow, along with CO_2 and ammonia to provide carbon and nitrogen respectively. Some of the CO_2 will be captured directly from the air at a visitors' centre at the factory, Vainikka says, and the rest will come from industrial sources.

The end result will be a yellow powder called Solein that is made of bacterial cells and is up to 70 per cent protein. It can be used as an ingredient in all kinds of foods, from meat alternatives to cereals and snacks. For instance, it can replace eggs in noodles and pasta. "We are aiming at replacing animal-sourced proteins, which we think have the highest environmental impact," says Vainikka.

"We are aiming at replacing animal proteins, which have the highest environmental impact"

Solein was approved as a food ingredient in Singapore in October 2022, and Solar Foods is awaiting approval in the UK, the European Union and the US.

Compared with plant crops, Solein will use 100 times less water per kilogram of protein produced, 20 times less land – including the land used for energy production – and emit a fifth as much CO_2, according to Solar Foods. Compared with beef, a kilogram of protein can be produced using 600 times less water and 200 times less land, again counting the land used for energy production, while emitting 200 times less CO_2, says the company.

There are other benefits, too: factories could be situated anywhere in the world and production won't be affected by weather extremes.

"With Solar Foods and other companies scaling up their systems, this is truly ushering in a new era of agriculture," says Dorian Leger at Connectomix Bio in Germany. "I think these trends are exciting and will lead to improved global food security and help bending the carbon curve." ▮

Solein, a protein-rich food (below), can be used as an ingredient in noodles (above)

TUUKKA KOSKI

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Solar system

To the moons of Jupiter and beyond

Two spacecraft launching in 2023 will aim to explore some of the solar system's smaller bodies, in an effort to understand how worlds become habitable, says **Leah Crane**

SMALL planetary bodies will be the big focus of space exploration in 2023. With the launches of two flagship missions, one to the moons of Jupiter and another to a strange metal asteroid, we are poised to solve many of the mysteries surrounding how these tiny worlds formed and what they are like today. The findings should lead to a greater understanding of habitability in our solar system more generally.

The first mission is the Jupiter Icy Moons Explorer (JUICE), due to launch in April 2023 and arrive in the Jupiter system in 2031. This orbiter from the European Space Agency (ESA) is designed to explore three of Jupiter's major moons: Europa, Callisto and Ganymede. All are thought to have oceans of liquid water beneath their frigid shells, and because water is crucial to life as we know it, learning more about those buried seas is a top priority.

"The one aspect we are most interested in is the liquid oceans, and in particular with Ganymede – we don't know where the ocean is, we don't know the depth of the ocean – what is the composition of these oceans, the amount of salt or dust," says ESA's Olivier Witasse, the mission's project scientist. "These are all questions that we will answer with JUICE."

While the science goals of JUICE are far-ranging and it has instruments to study the moons' surfaces and tenuous atmospheres, as well as Ganymede's strange magnetic field, the most exciting prospect is moving towards the ability to hunt for life there, says Witasse.

"Really, the goal of JUICE is to understand if life could be there, or if it could have been there in the past," he says. "If the conditions are right, then we will want the next mission to land, to send something under the crust to explore the ocean."

We know even less about the target of NASA's Psyche mission, due to launch in October 2023. It is headed to an asteroid, also called Psyche, that researchers believe to be an exposed iron core of a young planet. The spacecraft will arrive in 2029.

PETER RUBIN/NASA

Not much is known about the asteroid Psyche, but that is set to change

"We don't know what we're going to find, and with any luck, we're going to be completely surprised," says Lindy Elkins-Tanton at Arizona State University, the principal investigator of the mission. "There's a point in the proposal process when you have to write down the percentage improvement over the previous data, and we just wrote infinity, infinity, infinity, because there was no previous data. We are pretty confident that it's largely made of metal, but we really don't know much else."

Studying planetary cores is nearly impossible on actual planets because they are so deep underground, so Psyche could present a unique opportunity to directly observe a key building block of planets.

"The core is crucial to the properties of the Earth, in terms of creating the magnetic field and radiating a lot of the planet's heat," says Elkins-Tanton. "One of the ways to answer why Earth is habitable is to study how it was built, what it's made of, and Psyche is part of that story."

Habitability in our solar system is still a huge mystery, but the two spacecraft launching in 2023 should bring us one step closer to understanding it.

8

NASA engineers working on the Psyche spacecraft in March 2021

NASA/JPL-CALTECH, PETER RUBIN

"The goal of JUICE is to understand if life could be found on some of Jupiter's moons"

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Agriculture

Saving free-range birds

Without widespread vaccination of birds against avian flu, free-range poultry and eggs could be off the menu forever, finds **Madeleine Cuff**

Domestic geese roaming outside is now a rare sight in some European nations

KLEIN & HUBERT/NATUREPL.COM

9

ACROSS Europe, many families will have skipped their traditional Christmas roast turkey. Poultry meat and eggs are in short supply amid a catastrophic outbreak of avian flu.

Increasingly, it is looking as if the only way to save the poultry industry is if birds like turkeys and chickens are vaccinated against the H5N1 virus behind the latest outbreak, and European governments seem to be willing to make that happen.

Since October 2021, H5N1 has hit birds across Europe and the US. Seabirds have died on beaches, birds in parks have collapsed and been culled and millions of farmed birds have been slaughtered to try to stop the spread of the virus.

Farms face tough biosecurity rules and in the UK, for example, housing orders have kept birds indoors for months at a time – even those reared as free range – to avoid contact with wild birds that might carry the virus.

Despite this, almost 100 million domesticated and wild birds have died as a result of the disease since the start of last winter in the northern hemisphere, roughly half of them in the US and half in Europe.

"I know that the public wants chickens in their natural environment," says Nancy Beerens at Wageningen Bioveterinary Research in the Netherlands. "But… at this moment, keeping poultry outdoors, it's just not a possibility."

Avian flu vaccines have been effective at controlling H5N1 in places like Egypt and Hong Kong. Munir Iqbal at the Pirbright Institute in the UK says the avian flu situation in Western countries has changed drastically in recent years and vaccination should be considered, particularly for free-range flocks.

"People are worried you will get infected flocks of poultry, in which you don't see they are infected"

Beerens shares this view. "The only option is to vaccinate poultry," she says.

But vaccination isn't a perfect solution. If you detect that a bird has antibodies to avian flu, it is hard to tell if that is because it is infected or if the antibodies were produced following vaccination. Plus, vaccines may prevent serious illness, but might not stop a bird infecting another.

This means countries often don't buy birds from nations using vaccines. "People are worried that you will get infected flocks of poultry, in which you don't see that they are infected," says Beerens. To introduce mass vaccination, countries will need new trading protocols, she says.

Poultry vaccination shouldn't be a problem for consumers at least, says Iqbal, because it doesn't pose a risk to humans and vaccines are routinely given to some poultry, for example to protect against salmonella.

The scale of the problem seems to be bringing governments round to the idea of mass vaccination. France, Italy and the Netherlands are running vaccine trials, and the UK's chief veterinary officer, Christine Middlemiss, says UK government thinking on the issue has altered. "There's not going to be a vaccine in a few months. But what has changed is this global conversation and absolute desire to explore it." ▮

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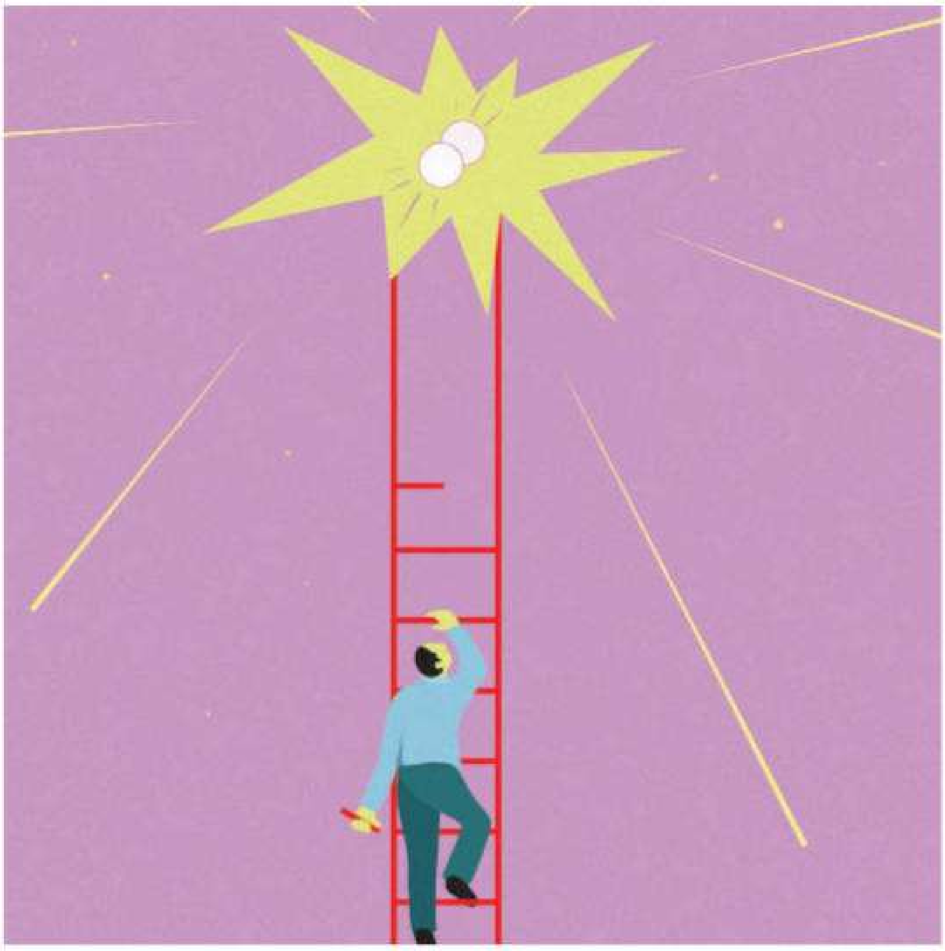
Reaching for the stars

It took generations of work to reach this month's nuclear fusion milestone, but there are big challenges ahead, says **Matthew Sparkes**


MICHELLE D'URBANO

FOR the first time on Earth, a controlled fusion reaction has generated more power than was used to kickstart it. Reaching the milestone provides real hope that fusion reactors can deliver on the decades-long promise of abundant, clean energy that, according to the Atomic Energy Commission in 1954, will be "too cheap to meter".

With 100 years of science behind the result and decades of engineering still ahead, fusion will be – if we get there – perhaps the best example of coordinated, long-term effort by humans and the greatest pay-off ever received. The engineers who construct the first commercial reactors probably haven't been born.

On 5 December, the National Ignition Facility (NIF) at the Lawrence Livermore National Laboratory (LLNL) in California fired up: 192 of the world's most powerful lasers compressed a tiny capsule of fuel, kickstarting a reaction that replicated the one at the heart of our sun.

NIF's lasers drew, for a few billionths of a second, 500 trillion watts – more than the output of the entire US national grid. The diamond-shelled fuel capsule they targeted is made to be 100 times smoother than a standard mirror because imperfections the size of a bacteria can stymie the reaction.

The lasers put out just over 2 megajoules of power, but the reaction provided 3.15 megajoules. This tiny energy gain would barely heat a bath, and the lasers drew 300 megajoules from the grid to run, but the significance was far greater: fusion power became not just theoretically possible, but demonstrably so.

Fusion is a perfect example of what UK Astronomer Royal Martin Rees calls "cathedral thinking", the idea that multiple generations of coordinated effort are needed to solve science's grand challenges, just like the stonemasons who worked on Ely Cathedral in southern England, knowing they would never see it complete.

As LLNL director Kim Budil said, announcing the news, it took generations of engineers and scientists to get here. "This is how we do really big, hard things."

You can trace these results back more than a century to Francis William Aston's discovery that four hydrogen atoms are heavier than a single helium atom, implying that if you combine the former into the latter, there is some mass unaccounted for that can be turned into energy. It is this process we are now learning to tame, thanks to the work of scientists from almost every corner of academia.

Ironically, for a technology that has the potential to avert global catastrophe, NIF was borne out of the US nuclear weapons programme, originally intended – and still used – as a way to recreate the conditions inside the nuclear bombs that anti-testing treaties mean can no longer be detonated.

Experts are divided on how far off fusion power is. But the old joke that it is 30 years away, and always will be, could be losing relevance. And while it would be foolhardy to pin all our hopes on fusion solving climate change, it represents a huge opportunity.

There are big challenges ahead, for NIF and alternative designs such as the JET and ITER tokamak reactors. To realise commercial fusion energy with a design like NIF, you have to do a lot of things that are currently impossible. At the moment, the experiment fires once, for a few billionths of a second, then takes hours to cool. A viable reactor needs to ignite constantly, reliably and for long periods without maintenance. How we achieve that isn't obvious.

But construction on NIF started in 1997 and the technology dates back to the 80s and 90s. There is good reason to believe that improvements are available. Time will tell which reactor design will be the first to go into commercial production, but when it does, the designers will be standing on the shoulders of many thousands of scientists and engineers. ▮

Matthew Sparkes is a reporter at *New Scientist*. @Sparkes

Our Human Story

We didn't start the fire

When did hominins start deliberately exposing their food to heat to make it better? Evidence of cooking is being pushed further back all the time, finds **Michael Marshall**

Michael Marshall is a science writer based in Devon, UK. He writes *New Scientist*'s monthly email newsletter Our Human Story, about human evolution. His book *The Genesis Quest* is about the origin of life on Earth and is now available in paperback

A THIS time of year, as the temperatures drop, I find myself craving pies. I don't know what unrecognised geniuses invented pastry and then had the idea to put a casserole inside it, but I owe them an unpayable debt. So let's talk about the invention of cooking. How long have humans been deliberately exposing their food to heat to make it better?

You might remember a recent story reporting evidence that hominins were cooking carp fish in an earthen oven around 780,000 years ago in what is now Israel. Previously, the oldest unambiguous evidence of cooking was from 170,000 years ago in South Africa.

The baked carp predates our species, *Homo sapiens*, by hundreds of thousands of years, so the chefs must have been Neanderthals or other extinct hominins. This is supported by another recent study, which described pulses that had been pounded and charred at caves in Greece and the Kurdistan region of Iraq. These sites are more recent, within the past 100,000 years, but Neanderthals are still the most plausible candidates for the cooks.

So we now know for certain that cooking isn't unique to our species and that it was going on 750,000 years ago. What's more, ovens are a fairly advanced form of cooking, compared with holding your food over a fire. To me, that's a hint that cooking goes back even further.

For over 20 years, Harvard biologist Richard Wrangham has been promoting the hypothesis that hominins started cooking around 2 million years ago. That's not long after our genus, *Homo*, evolved. Crucially, it is when brains evolved to be much bigger. Wrangham argues that cooked food, which is more nutritious and easier to chew, enabled the evolution of large brains.

When he first suggested it, this was a big swing because hard evidence of cooking was confined to relatively recent periods. However, absence of evidence isn't necessarily evidence of absence. The most obvious traces of cooking are organic remains, which tend to decay – unlike resilient things like stone tools.

And as the years have passed, the evidence of cooking has been pushed back. Traces of ash and burned bone from a South African cave hint at cooking 1 million years ago, while a site in Kenya has evidence of hominins roasting meat on fires 1.5 million years ago.

"We can get clues about the earliest hominins' relationship with fire by looking at modern apes"

The evidence for cooking sits alongside the growing evidence for controlled use of fire by extinct hominins. The tricky thing about the archaeological record of fire is that fires happen all the time anyway. Researchers must discern those started and controlled by humans from ordinary forest fires. In 2011, a systematic review found that controlled fire use could be traced back 400,000 years. That's before the origin of our species, so Neanderthals (and possibly other hominins) could control fire.

In June, I was delighted to read about evidence of controlled fires 1 million years ago, in what is now Israel. Key here was the method. The team studied flints that showed no visible sign of having been heated. Examination of their response to UV light showed their crystal structure had been altered by heating to around 400°C. This form of evidence could be more widely preserved and has the potential to show that *Homo* had control of fire 2 million years ago.

I should also mention the recent report that *Homo naledi*, ancient humans that lived in what is now South Africa, may have used fire to cook and to navigate in dark caves. The evidence for this comes from the Rising Star caves where the species' bones were found. Deep in the caves, there are "huge lumps of charcoal, thousands of burned bones, giant hearths and baked clay", according to Lee Berger at the University of the Witwatersrand in South Africa. That's dramatic, but it comes with a colossal caveat: the team hasn't dated this stuff yet, so it might be nothing to do with *H. naledi*.

H. naledi lived relatively recently, between 230,000 and 330,00 years ago, so their putative fire use wouldn't extend the period in which hominins have controlled fire and cooked. However, *H. naledi* had small brains for such a recent hominin, so if they could do it, maybe earlier hominins were capable of it too.

We can get some clues about the earliest hominins' relationship with fire by looking at modern ape behaviour. A study published in April showed that savannah-dwelling chimpanzees often prefer to travel in regions that have recently been burned, and that they find more food in those places. It's not hard to imagine hominins shifting from this passive use of fire to something more active. But when they did so remains wildly uncertain.

Taken together, all these studies have swayed my opinion about the cooking hypothesis. I'm still not convinced Wrangham is right, but my internal needle of scepticism has shifted. And now I want a pie. ■

Michael's week

What I'm reading

R. F. Kuang's Babel, *a fantasy in which translation is magic, and which I already know is going to be one of my favourites of 2022*

What I'm watching

I'm catching up with season four of Star Trek: Discovery *and wishing the writers would flesh out the bridge crew*

What I'm working on

A series of articles tackling key ongoing questions about covid-19

Up next week:
Chanda Prescod-Weinstein

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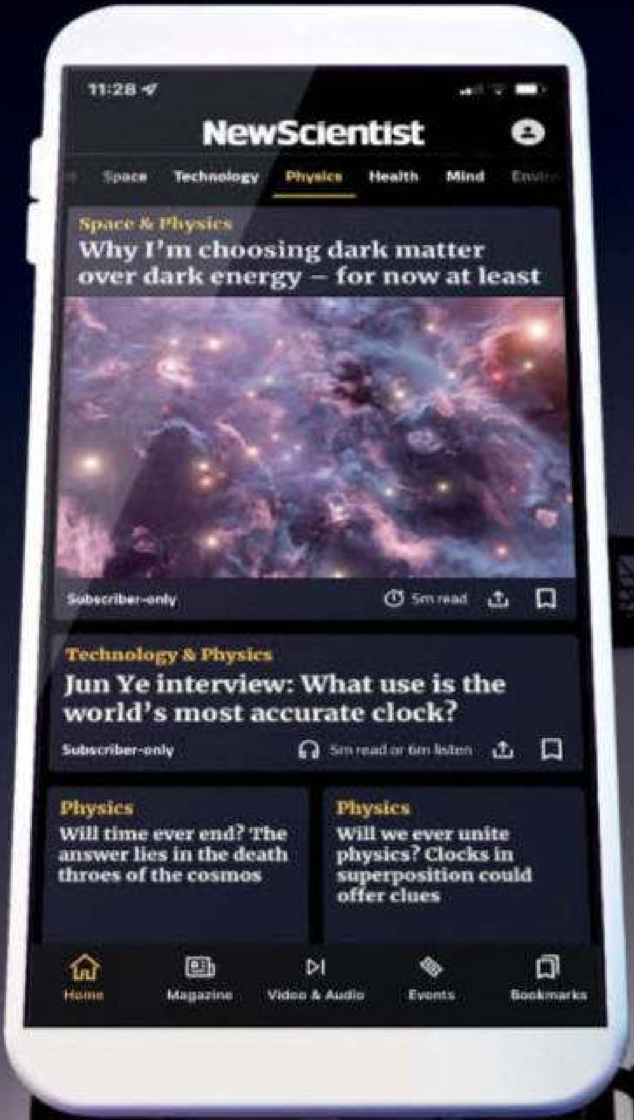

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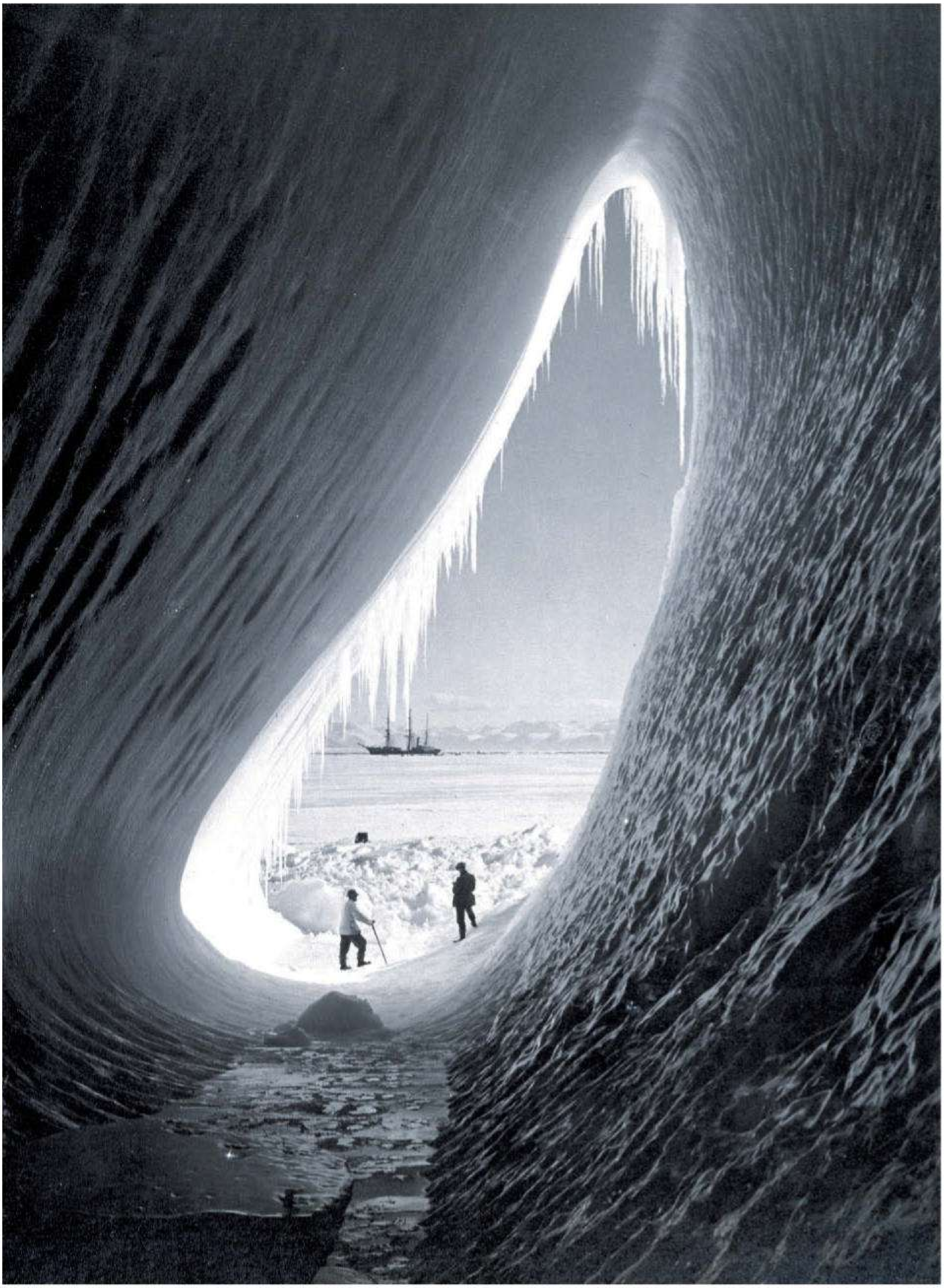

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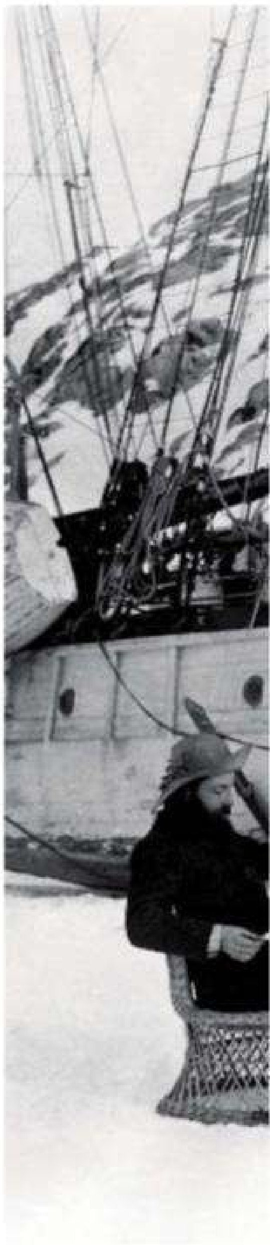

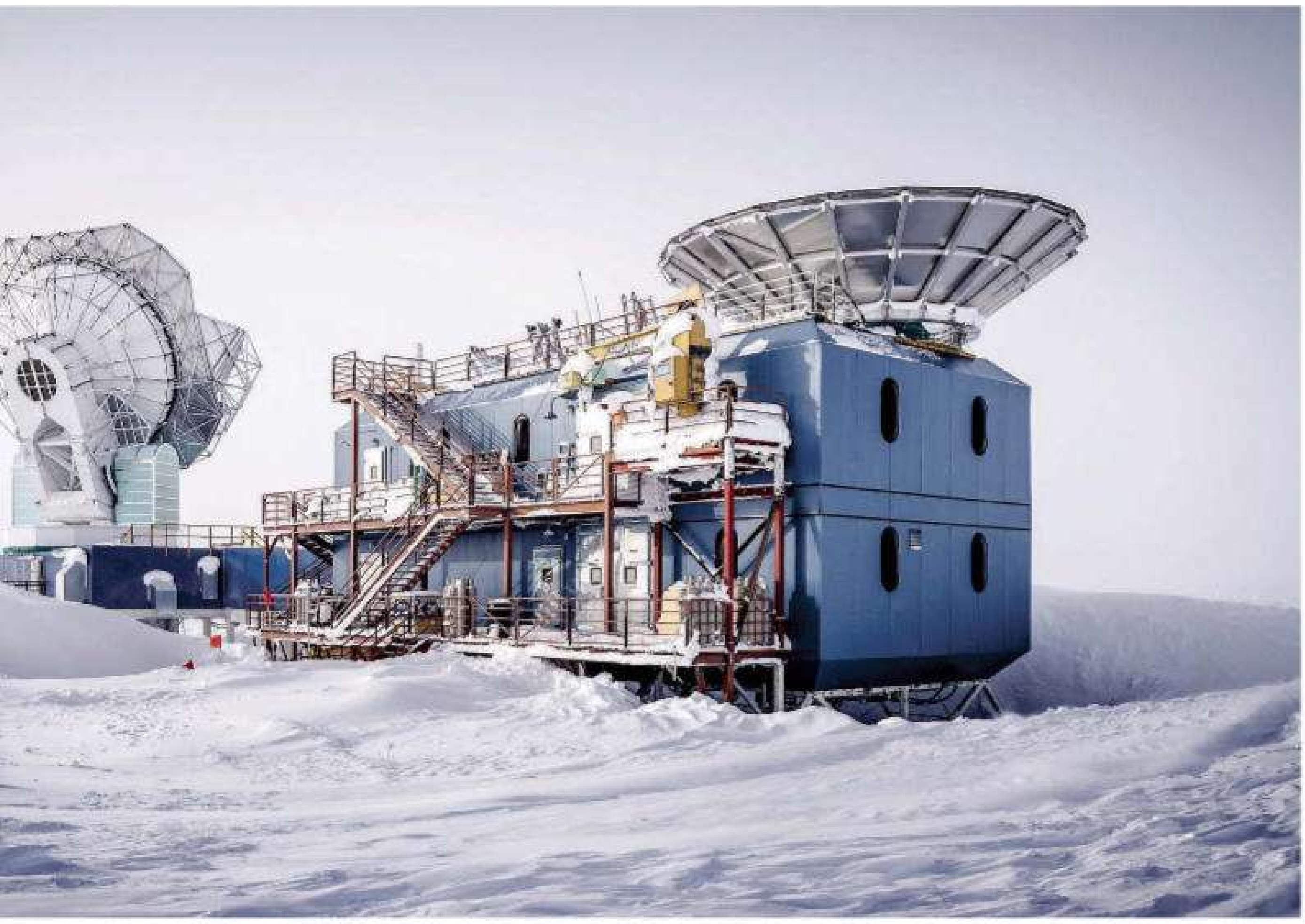

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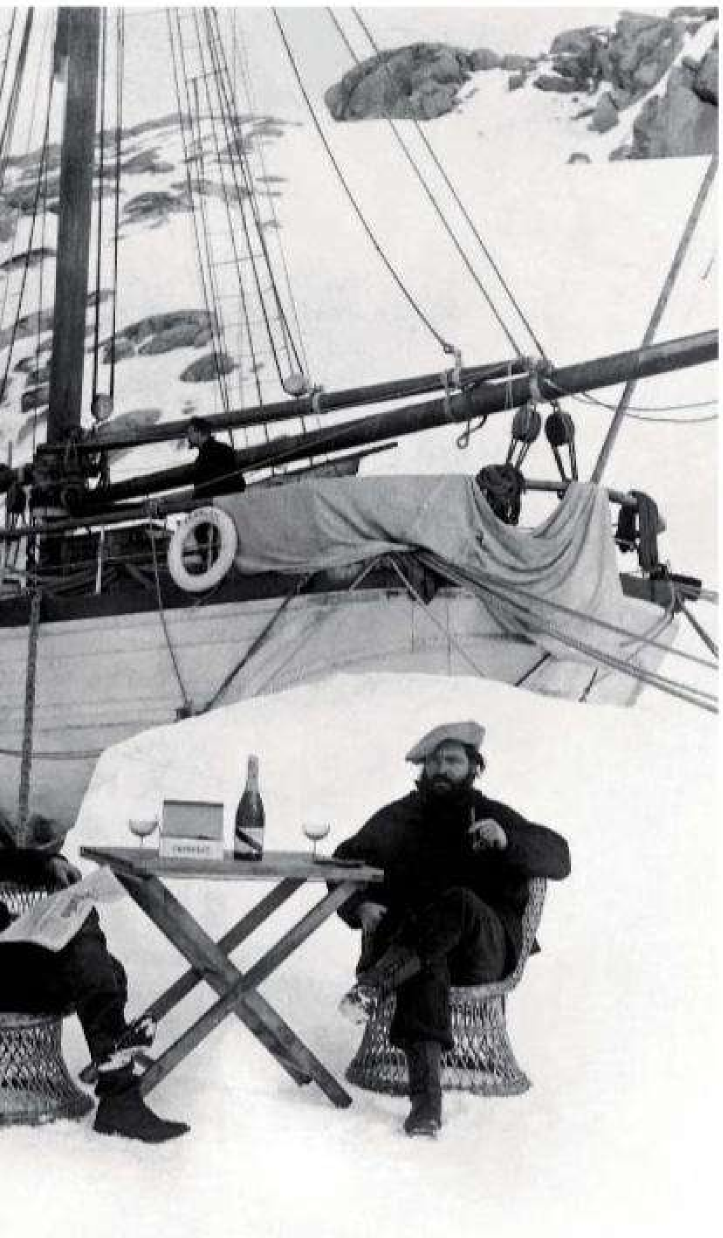

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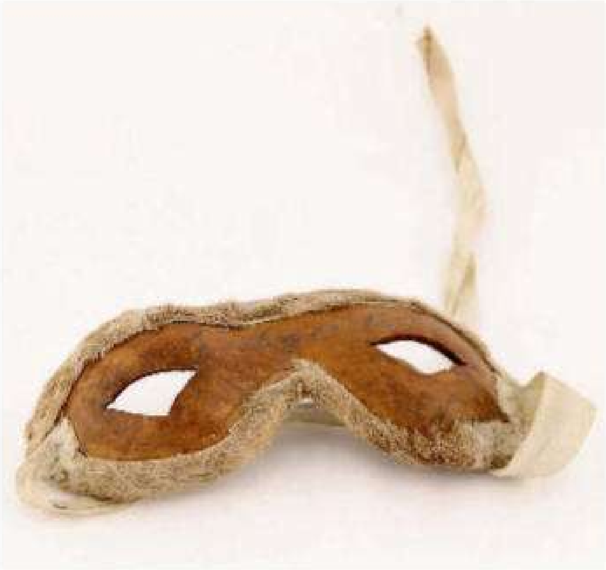

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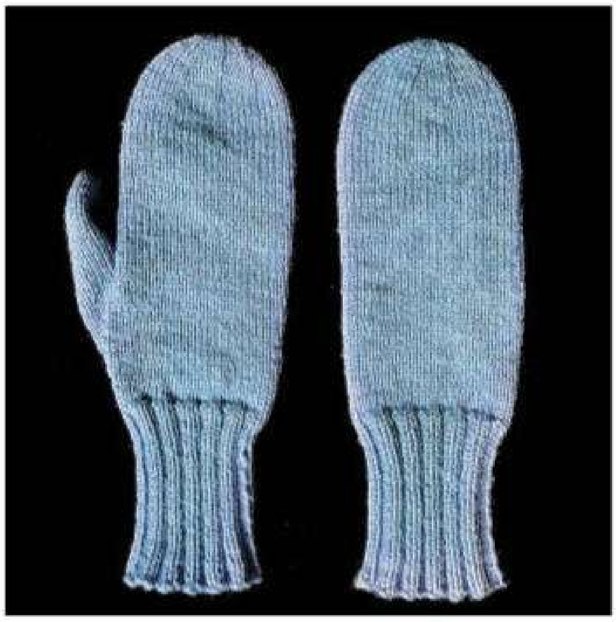


UNITED STATES NAVY HISTORY AND HERITAGE COMMAND

Cold snaps

Publisher Conway

THE first documented crossing of the Antarctic circle was made on 17 January 1773 by James Cook on the HMS Resolution. Now, 250 years later, Jean de Pomereu and Daniella McCahey are marking its anniversary in *Antarctica: A history in 100 objects*, a book that tells the story of the continent via 100 photos and artefacts from around the world.

On the far left is an iconic photograph taken from a grotto in an iceberg in 1911 by Herbert Ponting (pictured overleaf). Ponting was the first professional photographer to travel to Antarctica, after being invited by Robert Falcon Scott to join his ill-fated expedition. The ship is the Terra Nova and the men are geologist Thomas Griffith Taylor and meteorologist Charles Wright.

At top right are the South Pole Telescope and BICEP (Background Imaging of Cosmic Extragalactic Polarization) experiment at the Amundsen-Scott South Pole Station. The telescope helped to capture the first image of a supermassive black hole in 2019.

Leather goggles to protect against snow blindness, made during Roald Amundsen's 1910-1912 Antarctic expedition, are shown at middle right. Pictured below them are mittens knitted by Edith "Jackie" Ronne during an expedition in 1946-48. Ronne was one of the first two women to winter in Antarctica as part of a geographical expedition.

The central bottom image shows Ernest Gourdon and Paul Pléneau sharing a bottle of champagne in July 1904. This was intended to promote Mumm Cordon Rouge, since the Mumm family was a sponsor of the trip.

Alison Flood

Images continue on the next page

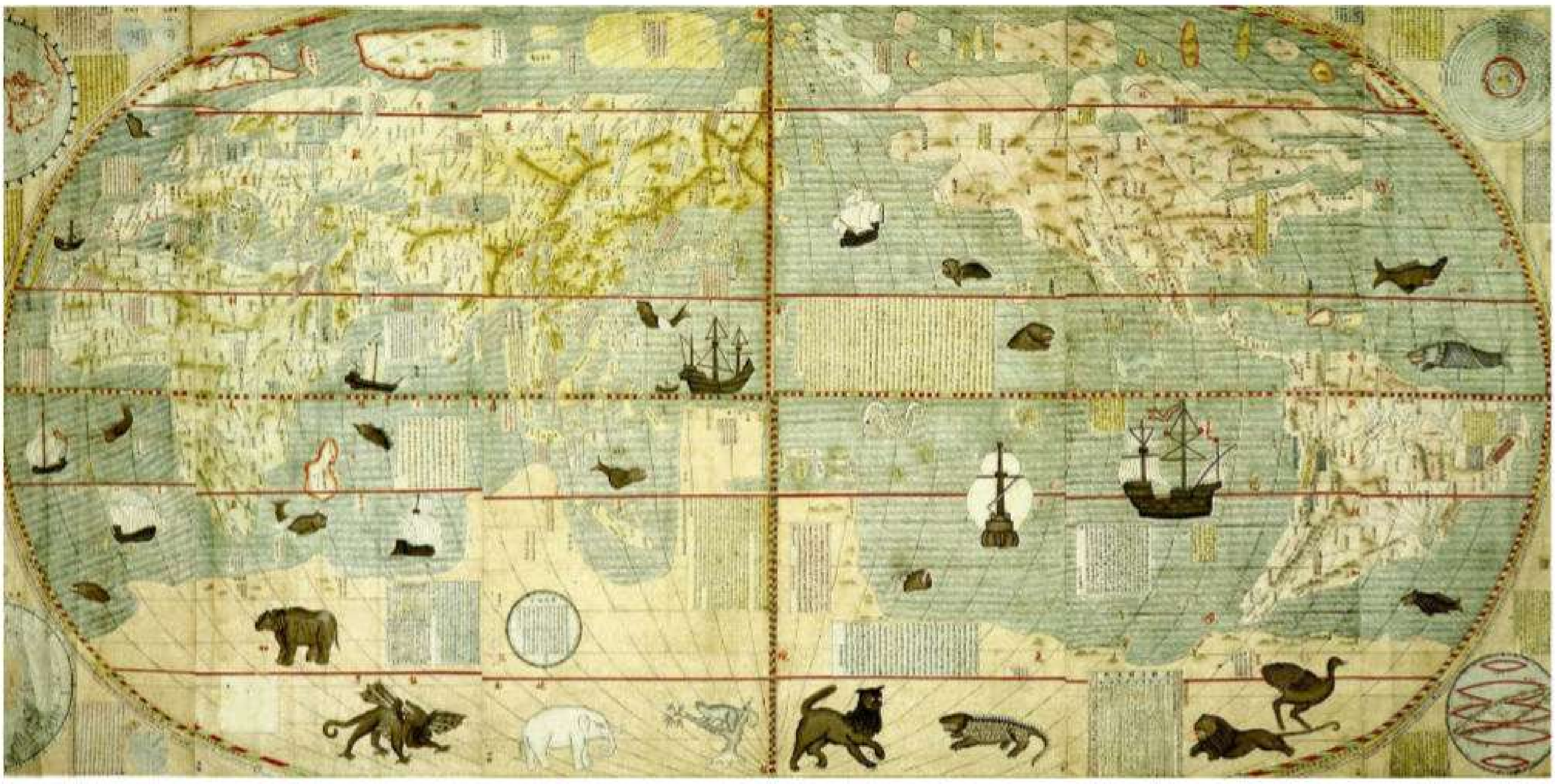
PABLO DE LEÓN/UNIVERSITY OF NORTH DAKOTA

(Clockwise from top left): A spacesuit tested in Antarctica in 2011 for possible use on Mars; a humpback whale skeleton reconstructed by conservationist and film-maker Jacques Cousteau on King George Island in 1972-73, to raise awareness of whaling; an anemometer from a 1908-10 expedition; a New Zealand $5 note commemorating Edmund Hillary, whose team was the first to reach the South Pole using overland vehicles, in 1958; the 1602 Kunyu Wanguo Quantu map from China, featuring a vast "Terra Australis" with the inscription "Few have reached these southern regions. So the things are not explored yet"; Scott expedition photographer Herbert Ponting in Antarctica in 1910; *Coryphaenoides lecointei*, a fish specimen collected in the Antarctic on 15 March 1899

SEBASTIAN COPELAND

FRÉDÉRIC PERIN/MÉTÉO FRANCE

HERBERT PONTING/ROYAL GEOGRAPHICAL SOCIETY VIA GETTY IMAGES; FAR LEFT: RBINATURAL SCIENCES



FINE ART IMAGES/HERITAGE IMAGES

Editor's pick

Knowing thyself is like a third-party observation

10 December, p 36

From John Cantellow, Derby, UK

Daniel Cossins seemed surprised at the agreement between his own self-perception and the perception of others of his nature. At heart, though, both can be regarded as observers' perceptions.

None of us consciously listens for a fire alarm, but our non-conscious mind continuously monitors our environment. When it hears the alarm, it recognises it as a potential threat to our survival, which takes highest priority for our conscious attention, and so switches our conscious attention to the alarm.

Our non-conscious mind determines that which we pay attention to, but we can't directly know the values it uses to do so. We infer from our restricted conscious awareness what those values are, and hence who we are. In that sense, we are just as much observers of ourselves as others.

For politics that takes the long view, look at Wales

Letters, 3 December

From Peter Leach,
Nercwys, Flintshire, UK

Lloyd Timberlake takes aim at the inability and unwillingness of politicians to take account of the impact on future generations of current policy decisions.

In 2015, the government of Wales introduced the Well-being of Future Generations (Wales) Act 2015, which requires public bodies there to take the long-term impact of their decisions into account. The act is attracting interest from countries around the world.

This measure attempts to address the concerns raised by Timberlake. It affects all policy decisions taken in Wales and isn't always popular. Some high-profile road-building projects, for example, have been scrapped when the "long view" has overridden "short-term" traffic difficulties.

From Roy Harrison,
Verwood, Dorset, UK

If I lived in the US, I might be as pessimistic as Timberlake regarding climate change. However, I find solace in the ability of technological progress to reduce the sacrifices that need to be made. We should also remember the strategic vulnerability of societies dependent on fossil fuels and not assume that action must come from governments – most revolutions come from the people.

From Neil Shillito,
Norwich, Norfolk, UK

Timberlake highlights the inertia and total absence of will of some governments to lead on climate change. Most governments know only too well that their shelf life is only about five years and therefore have no real incentive to act truly long term.

However, individual politicians and governments aren't the same thing. Many politicians are deeply concerned about climate change and do valuable work to push the agenda. Firms, charities, pressure groups and individuals too are doing more than their bit to ensure that governments at least do something rather than their preferred option of doing nothing.

We may not be around to see Y chromosome vanish

3 December, p 10

From Michael Zehse, London, UK

You report claims that the human Y chromosome will eventually be lost, in around 10 million years. It sounds very optimistic to imagine that humans will still be around so many years into the future.

With green hydrogen you get green oxygen for free

Letters, 26 November

From Blaise Bullimore,
Tiers Cross, Pembrokeshire, UK

Christopher Jessop's advocacy of green hydrogen is spot on. Furthermore, hydrogen generated by renewables-powered electrolysis comes with an immensely valuable buy one, get one free bonus at no extra energy cost: green oxygen.

Oxygen is the world's second most important industrial gas, with a market size of more than $30 billion a year. All current production methods are fuel and power intensive. Not only can adopting green oxygen slash carbon emissions, but where used to replace air in key industrial processes, they will run far hotter and thus at higher efficiency, while also eliminating pollution by nitrogen oxides.

This begs the question: as adopting green oxygen seems to be a no-brainer, where is the global push to jointly promote and exploit green hydrogen and green oxygen?

In pursuit of the health impacts of sweeteners

29 October, p 43

From Sam Edge,
Ringwood, Hampshire, UK

Your interview with Allison Sylvetsky about the current state of research on the metabolic effects of sugar-free sweeteners was interesting, if rather inconclusive. Clearly more research needs to be done with many more subjects.

I was heartened a bit to see the positive, if sparse, data about the natural sweetener stevia, although absence of evidence is not, of course, evidence of absence.

However, I didn't see any discussion of how the taste sensation of sweetness that these sweeteners offer might be acting through the brain's reward systems neurologically. What might be happening when the subsequent hit of sugar to the blood fails to turn up, I wonder?

It could never have been anything but like this

Letters, 3 December

From Tony Castaldo,
San Antonio, Texas, US

Nigel Tuersley writes about "the sheer improbability of [the fundamental constants of nature] being so finely tuned for life".

The word "improbability" implies the constants are being drawn from some probability distribution, but there is no evidence that the constants can be anything other than what they are.

There is also no evidence that the relatively tiny constants (compared with other constants) or the relatively large constants, or the small or large or "near 1.0" ratio of constants, are outliers of any kind; there is no evidence of any distributions, which means there is no evidence that any of these fundamental constants are members of the same distribution. ▮

For the record

- ▮ **Astronomer Tycho Brahe was Danish (26 November, p 44).**
- ▮ **Karl Flessa is a geologist (26 November, p 40 in the UK, p 36 in the US).**
- ▮ **In the answers to "A poo picture puzzle" (17/24 December, p 77), the final line of the snow leopard box was cut short. Apologies! It should have read: "This showed the animals' population density was about one leopard per 100 square kilometres – lower than previous estimates, which had probably counted the same animals twice."**

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Books to expand your mind

Long views of Earth, a world of numbers and electrifying insights from biology – there is plenty to inspire in 2023's best non-fiction, finds **Simon Ings**

INGO ARNDT/NATUREPL, DEIMAGINE/E+/GETTY IMAGES

Earth's past and future are reflected in this year's best books

***Frankenstein*'s creator**, Mary Shelley, would approve of our new forays into the mysteries and mechanics of life. Take *We Are Electric: The new science of our body's electrome* (Canongate) by Sally Adee, *New Scientist*'s books columnist (see "Ten top sci-fi picks", right). Adee explores the chemical and electrical ferment underpinning all growth and life, highlighting the pioneers and charlatans who discovered and exploited "bioelectricity". She also conjures electric medicine: a future of good health, regenerated tissue and (perhaps) extended life.

Shifting the focus to before birth is Leah Hazard's *Womb: The inside story of where we all began* (Virago). It is "the most miraculous and misunderstood organ", writes Hazard, a midwife and health campaigner. It is also the one about which we most argue and legislate. Can science bring clarity to the fraught business of birth? Does technology improve childbearing?

Eve: The disobedient future of birth (Profile Books) runs with this as Claire Horn, a criminologist and reproductive rights expert, looks with hope and trepidation to a future of externalised, artificial uteruses. Where do abortion, surrogacy and parenthood fit in a brave new "ectogenetic" world?

Mathematics helps us understand the world; computation helps us change it. In *Is Maths Real? And other questions that reveal mathematics' deepest truths* (Profile), Eugenia Cheng returns to her war against "maths phobia", asking and answering questions such as why must some mathematical operations be performed in a certain order to get the right result? And is maths even real? For Cheng, the common complaints about mathematics expose its greatest wonders, and hidden in our most innumerate fumblings is its great wisdom.

Physicist Michio Kaku looks to the future in *Quantum Supremacy: How quantum computers will unlock the mysteries of science – and usher in a new quantum era* (Penguin Press). While the best computers struggle to model the simplest of real-world systems, quantum computers are altogether different. Kaku brings his signature enthusiasm and optimism to bear on a vision of a time when it will be possible to manipulate reality at will.

Fancy adding a whole new dimension to your existence? Just add wings and set off for some epic journeys. Start with *Taking Flight: The evolutionary story of life on the wing* by Lev Parikian (Elliott & Thompson), who juggles birdwatching with a career as an orchestral conductor. The author looks for the commonalities between 13 of Earth's diverse flyers, from pterosaurs to dragonflies and butterflies to albatrosses, and contemplates the rhythms of flocking and migration.

If you find yourself walking in East Lothian, UK, look out for ecologist Katty Baird in forests, behind waterfalls and down holes, as she traps and observes the moths to which she has devoted her career. Her *Meetings With Moths: Discovering their mystery and extraordinary lives* (4th Estate) is a love letter to the natural world.

Dingy footman, Jersey tiger (pictured below) and pale mottled willow are some of the favourite moths of Tim Blackburn, an expert in invasive species and former director of the Institute of Zoology in London. In *The Jewel Box: How moths illuminate nature's hidden rules* (Weidenfeld & Nicolson), he shows how studies of unassuming moths have revealed a world of unseen ecological connections.

INGO ARNDT/NATUREPL

And then there is Naira de Gracia's *The Last Cold Place: A field season studying penguins in Antarctica* (Scribner). In it, de Gracia recalls her months following a generation of chinstrap penguins through their nesting season – and epic foraging journeys using their flippers (wings, honest) to help them swim, or "fly", underwater. It is a vivid account, full of natural beauty and brutality, laced with polar history and climate science.

From the deep history of continents to new visions of climate change, tackling the reality of our ever-changing Earth has never been more vital. Imagine the planet more than 2 billion years ago: teeming with life, but where the newly oxygenated air could kill in an instant. Imagine the evolution of animals struggling to adapt to a changing climate. In *Unearthing the Underworld: A natural history of rocks* (Reaktion), palaeontologist Ken McNamara finds incredible worlds preserved in stones we tend to ignore as he explores life's rocky roads.

In 2012, Ross Mitchell and researchers at Yale University predicted that Earth's next supercontinent, "Amasia", would form near the North Pole, as Asia and North America crunch together. We will know if they are right in 200 million years. Meanwhile, Mitchell's *The Next Supercontinent: Solving the puzzle of a future Pangea* (University of Chicago Press) tours past supercontinents and introduces us to the forces shaping the next one.

Closer to our own times, *The Paradox of Svalbard: Climate change and globalisation in the Arctic* by anthropologist Zdenka Sokolickova (Pluto) shows the human face of climate change. She tells of her two years in the town of Longyearbyen in the high Arctic, watching planes land and take off and listening to cruise ships sound their horns in the harbour. Climate change is well under way there, with higher temperatures, more rainfall, a rapidly thawing permafrost – and a way of life altered beyond recognition.

> "Rich repositories of history, culture and biodiversity, islands are disappearing one by one"

Christina Gerhardt's *Sea Change: An atlas of islands in a rising ocean* (University of California Press) celebrates islands as rich repositories of history, culture and biodiversity – and laments their loss as sea level rise redraws coastlines. The author, an environmental journalist, mixes cartography, science and history in a vivid, urgent testament to the climate crisis.

The further we travel, the more we learn about our quest to understand the cosmos. In *For the Love of Mars: A human history of the Red Planet* (University of Chicago Press), Matthew Shindell, who curates the spacecraft collection at the Smithsonian National Air and Space Museum in Washington DC, has plenty to say about why we look up at the stars. His history of Mars-driven hope and fancy includes Babylonian astrologers and Victorian scientists, some of whom brought extraordinary inventiveness to their search for intelligent life on Mars (pictured above).

NASA

After studying Earth from space, some astronauts end up thinking that everyone and everything on this planet is interconnected. How do the rest of us feel about that? *In Light-Years There's No Hurry: Cosmic perspectives on everyday life* (W. W. Norton), by Marjolijn van Heemstra, and translated by Jonathan Reeder, starts by listening to exoplanets and talking to the prisoners helping us to imagine human settlements on Mars. ▮

Simon Ings is *New Scientist*'s film columnist

Ten top sci-fi picks

From a telepathic moose to a Greek tragedy retold, 2023 looks electrifying, says **Sally Adee**

The Terraformers

Annalee Newitz (Tor Books)

This deep future from *New Scientist* columnist Annalee Newitz stars a Lone Ranger type and her partner, a telepathic moose. The mission: to keep interlopers off a planet under construction. Things go awry.

Collision

Edited by Rob Appleby and Connie Potter (Comma Press)

Authors worked with particle physicists at the CERN lab near Geneva, Switzerland, on this anthology, in which Stephen Baxter and Margaret Drabble's thought-provoking stories do more than glorify colliders.

Hopeland

Ian McDonald (Gollancz)

Super-powered people called Arcmages wield electricity in this fantasy sci-fi mix. It has time travel, a love story, the lot.

Julia

Sandra Newman (Granta)

Newman was picked by the Orwell estate to write a feminist retelling of George Orwell's *Nineteen Eighty-Four*, seen through the eyes of Winston Smith's lover, Julia Worthing.

TIMOTHY ALLEN/THE IMAGE BANK/GETTY IMAGES, NASA

In *The Lies of the Ajungo*, a boy journeys into the desert to save his mother

Arch-Conspirator

Veronica Roth (Tor Books)

A reimagining of Sophocles's Greek tragedy *Antigone* is set in a distant future where humans give birth to DNA surrogates. A child born naturally is said to have no soul. The action ends up surprisingly close to the source material.

In Ascension

Martin MacInnes (Atlantic)

Strange patterns in the ocean are among related phenomena from across the world that link up to suggest something beyond human understanding. This is an epic novel about our beginnings and endings.

The Lies of the Ajungo

Moses Ose Utomi (Tordotcom)

This Grimm's fable by way of West African lore is a must-read, as a boy journeys into the desert to save his mother.

Some Desperate Glory

Emily Tesh (Tordotcom)

Fans of military femme sci-fi and of queer space opera, take note. This is a book about how to pry your mind out of a fascist upbringing, and so much more.

The Landing

Mary Gentle (Gollancz)

A NASA scientist has trained all her life to deal with near-Earth objects, but when one arrives, it isn't what anyone expected.

Womb City

Tlotlo Tsamaase (Erewhon)

In a future Botswana, citizens are tracked by implants, creating an autocracy and domestic coercion. Folklore and ghosts are techno-futuristically mixed. ▮

Sally Adee is *New Scientist*'s sci-fi columnist

A year of gripping TV awaits

From more *Severance* and *The Mandalorian* to a much-awaited adaptation of *The Three-Body Problem,* **Bethan Ackerley** shares her viewing picks for 2023

ATSUSHI NISHIJIMA

LIANE HENTSCHER/HBO

Mark Scout (Adam Scott) in *Severance*; Ellie (Bella Ramsey) and Tess (Anna Torv) in *The Last of Us*

IN THE waning days of 2022, with little to do but gorge on Christmas leftovers, I find myself thinking about the coming year. Because sincere self-reflection is beyond me, however, all those thoughts concern television – and so I have amassed a non-exhaustive list of the nine shows I am most looking forward to in 2023.

If any TV series gives me hope for the medium's future, it is *Severance*, an unsettling workplace dramedy that debuted on Apple TV+ in February. We followed Mark Scout (Adam Scott) and his colleagues at Lumon Industries, who had agreed to have their memories of work surgically separated from the rest of their lives. Filming is under way, so we are likely to be blessed with more *Severance* in 2023.

I am limiting the Disney+ franchise juggernauts of Marvel and *Star Wars* to one pick each. Season two of *Loki*, set to air in mid-2023, is the most promising of the Marvel bunch thanks to its intriguing Time Variance Authority, which monitors the multiverse and can prune timelines if they are deemed too dangerous to exist. Indie filmmakers Justin Benson and Aaron Moorhead are set to direct most of the season, and their trippy, offbeat visuals are a perfect fit for a trickster god like Loki Laufeyson.

As for the *Star Wars* universe, I am eagerly awaiting the return of *The Mandalorian* and its heroes, bounty hunter Din Djarin (Pedro Pascal) and pointy-eared alien Grogu. When we last saw Din, his surrogacy of Grogu had estranged him from his fellow Mandalorians. Will the pair survive alone against the forces of the Empire? Find out from 1 March.

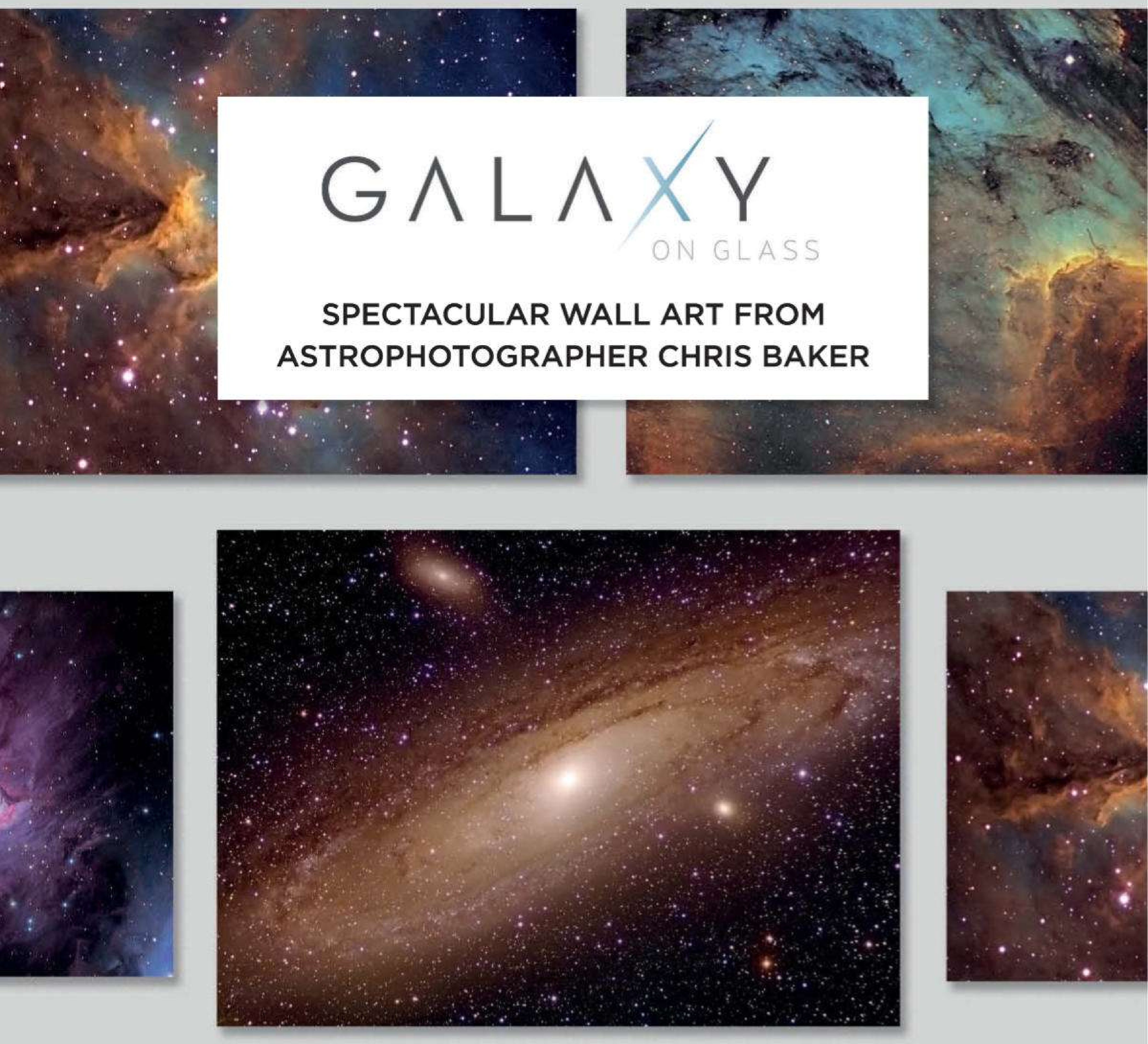
> **"In *Fallout*, survivors of nuclear war emerge from underground vaults into a 1950s-flavoured wasteland"**

To my delight, Pascal will also be back on screen with *The Last of Us*, airing on 15 January on Sky Atlantic and Now. Adapted from the best-selling video game of the same name, it is set in a post-apocalyptic world where a fungal pandemic has turned most of humanity into zombie-like monsters. Joel (Pascal) is a smuggler tasked with escorting teenager Ellie (Bella Ramsey) across a ruined US. The original game is a shattering tale of grief and sacrifice, and I hope the series lives up to its bleak beauty.

The Last of Us isn't the only video game adaptation on the roster. A far jauntier apocalypse awaits in *Fallout*, in which survivors of nuclear war emerge from underground vaults into a 1950s-flavoured wasteland. While there is no official date yet, this Amazon Prime Video series has been shooting since mid-2022 and will probably air before the end of 2023. For a completely different take on subterranean survival after a global disaster, try *Wool*, an Apple TV+ series based on Hugh Howey's *Silo* books. It is rumoured to hit screens in March.

Other novels being adapted this year include Bonnie Garmus's *Lessons in Chemistry*. Due to air on Apple TV+ at some point this year, this comedy, set in the mid-20th century, sees Brie Larson play Elizabeth Zott, a chemist turned TV cook who leverages her platform to teach science to suburban women. It will be a heady aperitif to a much-anticipated adaptation of *The Three-Body Problem*, a modern sci-fi classic written by Cixin Liu and brought to Netflix by former *Game of Thrones* producers David Benioff and D. B. Weiss. At once a tale of first contact with an advanced alien species and a meditation on China's Cultural Revolution, it will be a mighty task to capture the work's complexity.

Finally, *Extrapolations* – a long-awaited climate drama made by Scott Z. Burns, the producer of *An Inconvenient Truth* – airs on Apple TV+ in 2023. The series explores how climate change will touch every aspect of our lives, from love and family to work and faith. This star-studded production (Meryl Streep and Forest Whitaker are two of the big names in it) is sure to be one of the biggest shows of the year. Let's hope its climate message lives up to its cast. ▮



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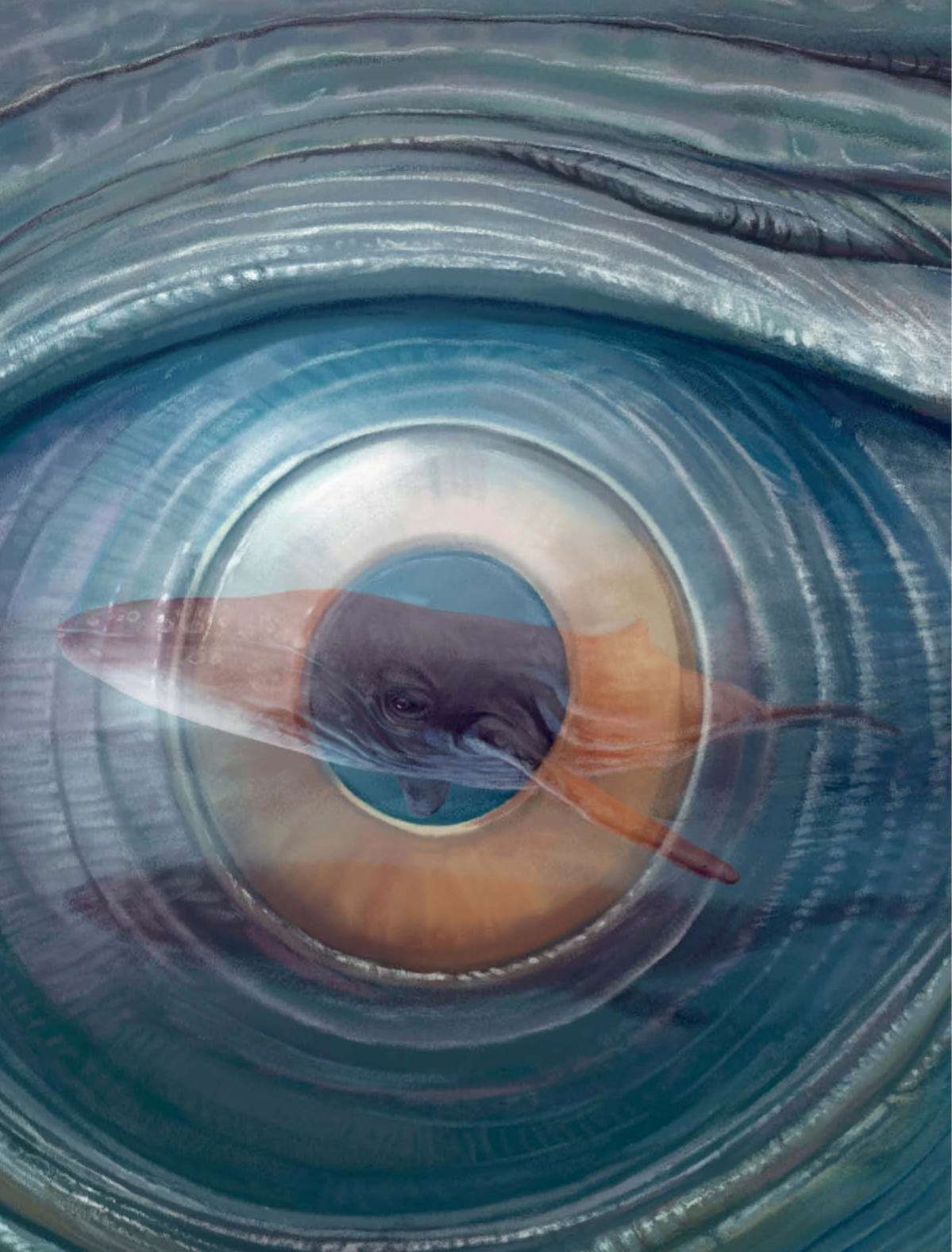


Gigantic beasts

Predatory reptiles that swam the seas some 200 million years ago may have been the largest animals ever, says **Michael Marshall**

PREHISTORIC Earth was a place of monsters. There were 2.5-metre-long millipedes, flying reptiles with 11-metre wingspans and snakes that weighed over a tonne. But if it is the biggest animal of all time you are looking for, conventional wisdom says you don't need to step back in time. The blue whale is known to reach 30 metres in length and to weigh 199 tonnes. Nothing else in more than half a billion years of animal evolution comes close, not even the largest dinosaur.

Conventional wisdom might be wrong. The fossil record may be concealing an animal that was even bigger than a blue whale. For decades there has been a slow trickle of evidence that a truly enormous super-predator swam the seas between 200 and 250 million years ago. Now, a string of discoveries and reanalysis of previous findings has dramatically bolstered the case.

The implications are far-reaching. We don't know exactly what this huge animal looked like and it doesn't even have a name. We have, however, begun to work out how such a gigantic creature could feed itself in the prehistoric seas. Confirmation that it outgrew the blue whale would tell us that we may have drastically underestimated how large toothed carnivores can grow. More than that, the discovery that such leviathans appeared shortly after the most devastating mass extinction in Earth's history suggests we may need to rethink the factors that drive evolution on such an epic scale.

When dinosaurs ruled the land, several groups of marine reptiles dominated the seas. There were the long-necked plesiosaurs, for instance, and the mosasaurs that looked like massive crocodiles with fins. Crucially for our story, there was also a third group.

Pioneering fossil hunter Mary Anning and her brother Joseph found the first fossils from this group in 1811 and 1812 in Lyme Regis on the south coast of England. They were described by the British surgeon Everard Home in a series of papers published between 1814 and 1820. Home was unsure how to classify the remains. In many respects they were reptilian, but in others they resembled the bones of a large fish. Over the next few decades, it became clear that the ancient animal was a reptile that lived in the sea and that it belonged to a broader group of similar animals. They were named the ichthyosaurs, meaning "fish lizards" in Greek.

The ichthyosaurs from Lyme Regis all existed in the Jurassic period, the middle of the three geological periods in which the dinosaurs lived. But as more fossils were found elsewhere in the world, it became clear that there were also ichthyosaurs in the later Cretaceous period and in the earlier Triassic period too.

The Jurassic and Cretaceous ichthyosaurs are all quite similar. They resemble a cross between a dolphin and a large fish such as tuna and could reach several metres in length. In January 2022, researchers including Dean Lomax at the University of Manchester, UK, unveiled the UK's largest known complete ichthyosaur skeleton, which was 10 metres long and found in 182-million-year-old Jurassic rocks in Rutland. It was clearly an impressive apex predator, double the length of a modern great white shark. But it was still only about a third of the length of the largest blue whales.

For larger ichthyosaurs, you have to wind the clock back to the Triassic. In 2004, the late Elizabeth Nicholls, who worked at the Royal Tyrell Museum in Alberta, Canada, and her colleague Makoto Manabe at the National Museum of Science and Nature in Japan reported a big discovery: huge fossilised ichthyosaur bones near the Sikanni Chief river in British Columbia, western Canada. They belonged to a new species, which the two researchers called *Shonisaurus sikanniensis*. It lived during the Triassic, about 218 million years ago, and it was enormous. With an estimated length of 21 metres, it has been recognised by Guinness World Records

›

RICHARD WILKINSON

as the largest marine reptile of all time.

The skeleton is "50 to 60 per cent complete", says Lomax. "That's your absolute largest skeleton of an ichthyosaur that is known."

Such large animals are rare in Earth's history. According to Martin Sander at the Natural History Museum of Los Angeles County, California, only a handful of animal groups have evolved an estimated body mass above 20 tonnes, including the long-necked sauropod dinosaurs and the whales. The ichthyosaurs were the earliest to do so – and it is possible some of them outgrew anything that followed.

In 2016, at Lilstock in south-west England, Paul de la Salle at the Etches Collection Museum of Jurassic Marine Life found what Lomax calls "this massive chunk of bone". It was 96 centimetres long. Careful examination by de la Salle, Lomax and their colleagues revealed it was part of a surangular bone from the lower jaw of an ichthyosaur. It is about 205 million years old, meaning the animal it belonged to lived close to the end of the Triassic.

"If one part of the jaw bone is a metre long, how big was the entire animal?"

If just one part of the jaw was almost a metre long, how big was the entire animal? Lomax says we can make an educated guess. If we compare how long the surangular bone was in relation to overall body length for closely related ichthyosaurs, then by scaling up we can estimate the length of the Lilstock ichthyosaur. That gave a range of 20 to 25 metres – larger than *S. sikanniensis*.

The discovery got Lomax and his colleagues thinking. About 50 kilometres along the coast from Lilstock, there is another fossil-bearing site called Aust Cliff. Between the 1840s and 1950s, five long shafts of bone were found there. They had been interpreted as limb bones from dinosaurs or other land-dwelling reptiles.

Lomax remembered that one had "a really strange groove that runs down the side" – unusual for a limb bone, but typical of an ichthyosaur jawbone.

An ichthyosaur snout showing its backward-pointing teeth

SINCLAIR STAMMERS/SCIENCE PHOTO LIBRARY

The team re-examined three of the bones and concluded that, sure enough, they were pieces of ichthyosaur jaws. Some of the Aust Cliff bones appear to have belonged to ichthyosaurs even bigger than the Lilstock specimen: "30-plus metres", says Lomax, perhaps even 35 metres.

In other words, larger even than a blue whale. "You are starting to get out to that point of truly gigantic contender for the world's largest animal," he says.

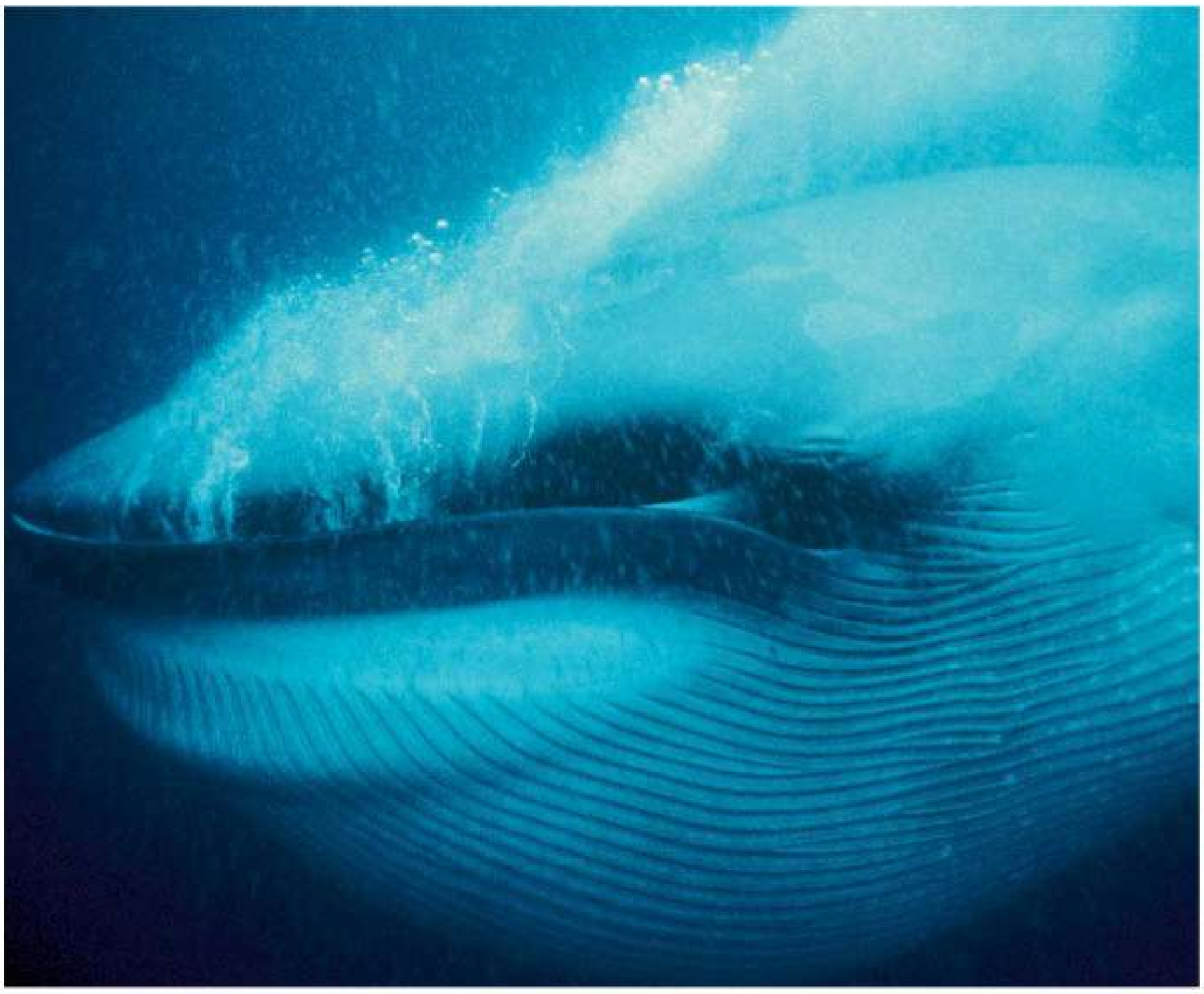
Lomax is at pains to emphasise that such numbers carry caveats. As species evolve, different body parts change size at different rates. It may be that the Aust Cliff and Lilstock ichthyosaurs had disproportionately large heads. In that case, their body lengths may not have been exceptional. Because the fossils are fragments, he says, the uncertainties are enormous.

But he isn't alone in entertaining the possibility that Triassic ichthyosaurs were exceptionally large. "These animals may well have been the largest that ever existed on this planet," says Sander. "And we know next to nothing about them."

For Sander, the evidence for these giant ichthyosaurs has been accumulating for over a century. He points to a paper from 1878 by geologist James Hector that describes a piece of ichthyosaur vertebra 45.7 centimetres in diameter. "If that is true, then that is by far the largest ichthyosaur," says Sander – at least as long as a blue whale and possibly longer. The bone was found in New Zealand, but frustratingly it was lost soon afterwards – possibly in the sinking of a transport ship. This means there is no way of confirming whether it really did belong to one of the world's largest ever animals.

Going large

The fact that the New Zealand ichthyosaur has vanished into the shadows seems curiously apt. At this stage, we know for sure that some Triassic ichthyosaurs reached 21 metres in length. We also have hints that a few grew much larger. Frustratingly, however, we lack



The blue whale is generally thought of as the biggest animal ever

DOC WHITE/NATUREPL

the complete skeletons that would tell us for sure if some outgrew the blue whale.

While we wait for a 35-metre ichthyosaur skeleton to show up, we can instead address some related questions – namely how and when did ichthyosaurs first evolve and why did they get so large?

The Triassic period was bookended by mass extinctions. The Permian-Triassic event of 252 million years ago is the worst extinction event known. "We cannot overstate how devastating [it] was," says Paige dePolo at the University of Edinburgh, UK. "Ninety per cent of the species in the ocean went extinct." Then, about 51 million years later, came the end-Triassic extinction, which is less famous and less well understood.

The Permian-Triassic extinction meant that, at the start of the Triassic, the oceans had been virtually stripped of animal life. The ichthyosaurs dived into this unpromising looking marine world just a few million years later. They had started out as land-dwelling reptiles, and by 248 million years ago – just 4 million years after the extinction – there were at least two types of proto-ichthyosaur: the 0.4-metre-long *Cartorhynchus lenticarpus*, described in 2014, and the 1.6-metre-long *Sclerocormus parviceps*, described in 2016.

Ichthyosaurs didn't stay small for long. In 2018, Lene Liebe Delsett at the University of Oslo in Norway and her colleagues described ichthyosaur remains from Marmierfjellet on the island of Spitsbergen off the north coast of Norway. Many of the bones were fragmentary, but enough remained to identify the animals as being several metres long. The remains date from the first 5 to 10 million years of the Triassic. "There were large ichthyosaurs really early," says Liebe Delsett.

Then, in 2021, Sander and his colleagues reported a real whopper. They described a 2-metre-long ichthyosaur skull, plus some other bones, found at a site called Fossil Hill in Nevada. The animal, which they named *Cymbospondylus youngorum*, was probably 17.5 metres long. It lived 246 million years ago, a mere 6 million years after the Permian-Triassic extinction, and only 2 million years after the proto-ichthyosaurs. The implication was clear: once they had taken to the water, some ichthyosaurs got very big, very fast.

Rapid change

At first glance this appears to be a shockingly fast pulse of evolution. For comparison, the whales seem to have taken tens of millions of years to evolve from land-dwelling animals to ocean giants. But given that the ichthyosaurs were living immediately after a period of profound ecological upheaval, perhaps we shouldn't be too shocked. "I suspect one of the key reasons for [their rapid evolution into giants] is simply because nobody else was doing that," says Lomax. It may be that such a rapid shift was possible because the Permian-Triassic mass extinction reduced diversity in the oceans, creating an opportunity for gigantic animals to evolve, which the ichthyosaurs seized.

If so, it means there is more than one way to evolve into a giant. A more fertile ocean is a known route. "The conventional explanation for gigantism in modern whales is that the cooling of the Earth resulted in an increased productivity, at least in certain places of the ocean, and this is why, when Earth entered the glacial cycle, whales could become bigger," says Sander. That isn't what happened in the Triassic.

That said, being large may have carried a similar benefit for Triassic ichthyosaurs and today's whales. "Nobody can eat you, which is a great advantage," says Liebe Delsett. When it comes to how such large animals feed themselves, we can get some insight by considering today's whales, which fall into two groups. Toothed whales like the sperm whale, which grow to lengths of 20 metres, are top predators: they hunt squid and other large prey in the deep sea. But the largest species, like blue whales, have no teeth. They are filter feeders that sift huge quantities of tiny plankton and krill from the water.

There is a reason why toothless filter-feeders can grow larger. Most marine ecosystems ›

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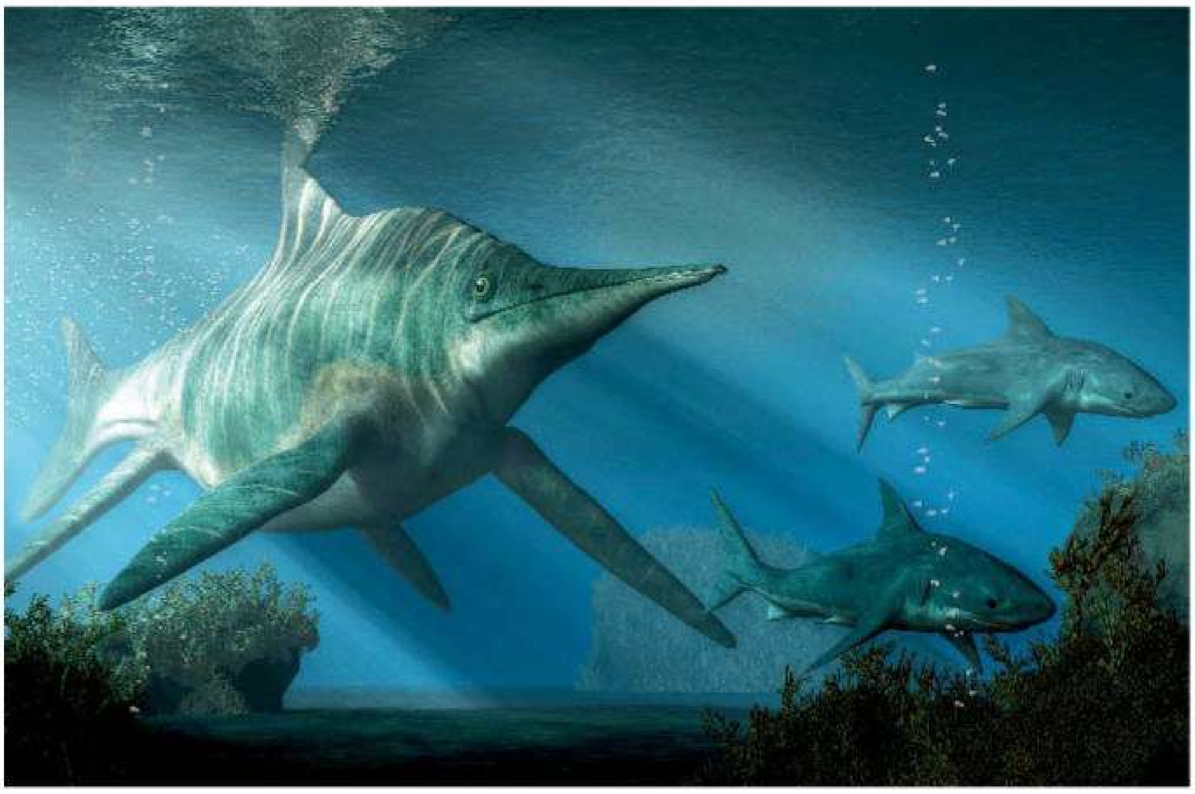


DANIEL ESKRIDGE/ALAMY

An artist's impression of *Shastasaurus*, a kind of ichthyosaur

depend on phytoplankton, "primary producers" that obtain energy from sunlight and convert it to sugars, like green plants on land. Small animals eat the phytoplankton, then larger animals eat the small animals, and so on. Food chains can only have so many steps, though, because at every stage nutrients are used up fuelling the metabolism of the animals in question.

The result is that a big animal will get the most energy if it bypasses a long food chain and eats phytoplankton or microscopic animals in huge quantities. The alternative – chasing down and eating larger animals – just won't provide enough energy to sustain a truly enormous animal.

Teeming seas

But it seems ichthyosaurs had the potential to grow enormous even if they had teeth and hunted like a sperm whale rather than filter fed like a toothless blue whale. When describing the 17.5-metre-long *C. youngorum*, Sander's team did some calculations to see how the Triassic oceans could have supported huge ichthyosaurs. It turns out that these oceans had quite short food chains, possibly because so many species had been recently wiped out in the Permian-Triassic extinction. The seas were teeming with ammonites – molluscs with coiled shells – and eel-like conodonts. Many of these animals had body sizes in the range of tens of centimetres, but being close to the bottom of the food chain, they would have supplied the ichthyosaurs with ample nutrition without the need for filter feeding.

"It used to be thought there was an upper limit for the ichthyosaurs because the primary producers that characterise our [modern] oceans hadn't evolved yet," says dePolo. That is no longer the case, she says. However, their large size may ultimately have been their downfall.

There is evidence that giant ichthyosaurs survived until the end of the Triassic. In 2018, Lomax and his colleagues described a single bone of *Wahlisaurus massarae*, another big species from the Triassic-Jurassic boundary, although exactly how large is still unclear. In April 2022, Sander and his colleagues described a 10-centimetre-long ichthyosaur tooth from the Swiss Alps. It came from an animal that Sander says may have been about 20 metres in length and lived at the very end of the Triassic.

Then came the end-Triassic extinction, which seems to have been caused by massive volcanic eruptions. At the time, all the continents were joined together in a single supercontinent called Pangaea, and as it started to break up huge volcanoes formed. Ichthyosaurs were one of the worst affected groups. Almost all the lineages died out, with only a few relatively small forms surviving into the Jurassic. The giant ichthyosaurs were no more.

It isn't clear why they vanished, but dePolo tentatively suggests their proposed diet of ammonites and conodonts may have been a factor. "Conodonts went extinct at the Triassic-Jurassic boundary, and there was a big turnover of ammonites," she says. The giant ichthyosaurs may have been doomed by their size, which demanded huge food intakes. This would indicate gigantic animals are particularly vulnerable to mass extinction events – a pattern that appears to be playing out again in the modern world, where larger mammals and birds are projected to fare worse this century than smaller ones.

That said, dePolo emphasises that the diet explanation is just a hypothesis. "The late Triassic is a confusing place," she says. The fossil record of the second half of the Triassic is "abominable", says Sander, with relatively few good sites, so it is hard to tell what was happening.

Whatever the exact chain of events, we now know that the end-Triassic extinction was far more significant than its obscure reputation might suggest. It wiped out a group of extraordinary gigantic animals – the world's first "super-predators", according to Lomax.

Enormous dinosaurs would rise and fall in the Jurassic and Cretaceous, the whales would begin their evolutionary journey later, in the Eocene. But it is just possible that the largest animals Earth has ever seen were the Triassic ichthyosaurs. We will know for sure only when they finally swim out of the shadows. ■

Michael Marshall is a science writer based in the UK and author of *The Genesis Quest*

CLAUDIO SERICANO

Melatonin mystery

Millions of people take melatonin supplements to aid sleep, treat jet lag and cope with night shifts. But do they really help, asks **Jules Montague**

IT IS sometimes referred to as the Dracula hormone because it emerges at night and lays low during the day. But most of us know it as melatonin, a hormone that has become intimately connected in our minds with nightfall and sleep. In the US, where melatonin supplements are available over the counter, millions of adults take them regularly to tackle insomnia, jet lag and night shifts. Thousands more dole out melatonin "gummies" to their children to help them sleep through the night. In the UK, melatonin is available on prescription for the short-term treatment of insomnia in people aged 55 and over and for jet lag.

A huge group, then, believes melatonin is the answer to its sleep problems. So, you may be surprised to hear that nearly a quarter of a century ago, researchers writing in the journal *Cell* cautioned against "melatonin madness". "Melatonin's [sleep-inducing] capability has... been embellished," they wrote. "The cure for melatonin madness is to ignore the hyperbole and histrionics and focus instead › on hypothesis testing and sound science."

It seems that few people listened to the warnings. In the US, melatonin use increased five-fold between 1999 and 2018 and recent news stories have reported increasing accidental ingestion of melatonin – the hormone accounted for 1 in 20 ingestions among children and young adults under 19 years of age reported to the US National Poison Data System in 2021.

Where does the truth lie? Can melatonin really improve our sleep? Emerging research suggests we have misunderstood its effect on our body and brain. So who should really be taking it, and what are the risks?

The story of melatonin really begins with translucent tadpoles. In 1917, researchers at Johns Hopkins University in Baltimore were investigating how extracts from the pineal gland affect growth. This gland is a tiny structure towards the bottom of the brain. Tadpoles were fed bovine pineal glands and within 30 minutes, these dark-skinned creatures became so translucent that their internal organs were visible. Three hours later, the tadpoles returned to their usual colour.

The mystery of what substance had induced this colour change took more than 40 years to crack. In 1958, Aaron Lerner at Yale University and his team isolated a hormone from the pineal gland that they named melatonin. Lerner, a dermatologist, initially thought it could treat conditions like vitiligo, in which patches of skin lose their colour. Later experiments showed that melatonin didn't hold the key to treating disruptions in skin pigmentation. Instead, further work identified melatonin as having an important role in circadian rhythms – internally driven daily cycles that coordinate various body processes, including sleep.

To explore melatonin's relationship with sleep, it helps to understand how sleep is regulated. First, there is what is known as sleep pressure. The longer you are awake, the more a chemical called adenosine is released by cells in the brain. Adenosine inhibits arousal and increases the drive to sleep. Caffeine blocks adenosine receptors, which explains why it can help you temporarily overcome tiredness.

Sleep pressure is balanced by the force of a 24-hour circadian rhythm, known as "circadian alertness", which is synchronised to the external environment and can be modulated by things like sunlight. Melatonin plays a key role in this synchronisation. Its synthesis is regulated by the brain's so-called master clock – the suprachiasmatic nucleus – to produce a circadian pattern of melatonin release, with levels rising at dusk, peaking between 2am and 4am and declining before dawn (see "The daily drive to sleep", below). The suprachiasmatic nucleus has receptors that detect melatonin, providing another cue for synchronisation.

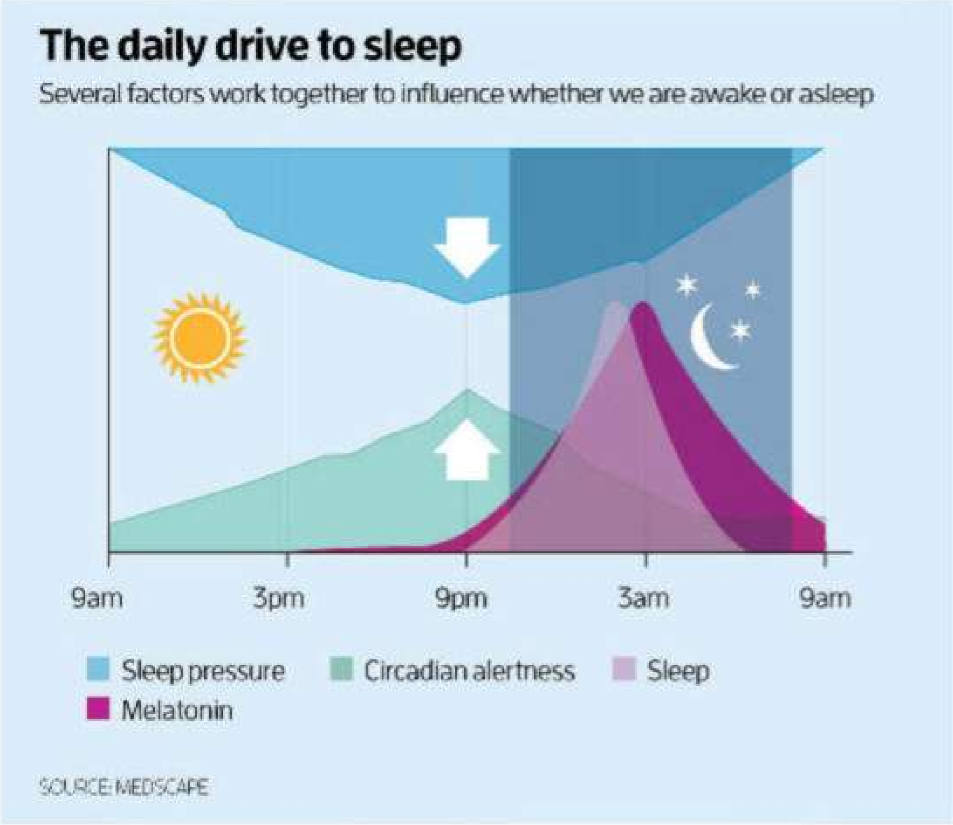
SVEN HAGOLANI/FSTOP IMAGES GMBH/ALAMY

Melatonin may help adults get to sleep quicker – but only by a few minutes

> **"Melatonin is a mild modulator of sleep, but it isn't how sleep is governed"**

Sleep is an intricately choreographed process, easily disrupted by jet lag or working night shifts. Both of these are related to a mismatch between our innate circadian rhythms and the external environment. With jet lag, we cross time zones too rapidly for our circadian clock to adjust. The suprachiasmatic nucleus can adapt to a disrupted social schedule and the different timings of light and dark at our destination, but it takes a while – about one day for each hour of time zone change. With night shifts, sleep pressure may increase after an exhausting stint at work, but just as your head hits the pillow, your body clock may insist it is time to wake up. This isn't helped by environmental cues, such as quiet streets, closed shops and dark skies during your shift, telling you everyone else is asleep.

No wonder melatonin was seen as a solution to sleep problems. Our urge to sleep closely correlates with the hormone's rise and fall, so people assumed it was the cause of sleep, says Russell Foster at the University of Oxford.



The daily drive to sleep

Several factors work together to influence whether we are awake or asleep

SOURCE: MEDSCAPE

ROXIROSITA/GETTY IMAGES

Some trials of melatonin have suggested it may mitigate the severity of jet lag symptoms

Initially, this idea seemed to be supported by case reports in the 1970s of people with spinal injuries who were paralysed from the neck down. They were unable to produce melatonin as a consequence of disrupted nerve signals and had extremely poor sleep. "People thought: 'Right, no melatonin equals awful sleep'," says Foster. However, researchers later compared these results with people with spinal injuries affecting just their legs, whose melatonin nerve signals had been spared and so could produce the hormone. Their sleep was just as bad. So, poor sleep in these groups was independent of melatonin production.

Further work shows that people who have had their pineal gland removed due to illness continue to experience circadian sleep and wake rhythms with little change in sleep. "When you take away melatonin in humans by these rather drastic means, it doesn't affect sleep very much," says Foster. In other words, melatonin is important for optimal circadian function, but not essential to it. It is one of many factors that together help to promote sleep. "Our propensity to sleep closely correlates with melatonin's profile, but we shouldn't mix this up with causation," says Foster. "Melatonin is a mild modulator of sleep, but this is not how sleep is governed."

Melatonin also turns out to have many other roles. It has antioxidant and anti-inflammatory functions, it regulates energy metabolism – including body weight, insulin sensitivity and glucose tolerance – and it helps control blood pressure.

Extra minutes

So does melatonin help you sleep at all? Well, that depends on who you are and how much extra sleep you are hoping for. The truth is that, for most adults, melatonin supplements will buy extra minutes of sleep, not hours. Hardly the stuff of dreams.

A 2013 meta-analysis of nearly 1700 participants found that, compared with a placebo, melatonin decreased sleep latency, or the time taken to fall asleep, by 7 minutes on average. Total sleep time increased by around 8 minutes. This year, an international meta-analysis of 154 trials that included 44,000 people also reached a disappointing conclusion: melatonin "did not show overall material benefits".

What about helping to "reset" the body clock to cure jet lag? Discerning melatonin's effect in this context has proved difficult, in part because the symptoms of jet lag disappear fairly quickly by themselves. England's decision to allow melatonin to be prescribed for the short-term treatment of jet lag was based on trials conducted between 1985 and 2005, many of which were small and didn't provide thorough outcome measures, used to assess the effect of the intervention. Half failed to detail the dose of melatonin or whether it was taken as a tablet or a liquid. And although some trials showed that melatonin lessened the severity of symptoms, none eradicated them completely.

There is more promise in another area, though: it may have benefits in children, especially those with neurodevelopmental differences, such as autism. In the UK, the licensed version of melatonin is used "off label" as a treatment to help sleep problems in children once non-pharmacological measures have been exhausted. In 19 randomised controlled trials, melatonin had a sizeable effect, cutting sleep latency in children by 11 to 51 minutes and boosting sleep duration by 14 to 68 minutes. These improvements were greatest in autistic children. Child and caregiver quality of life was often enhanced, too.

These positive results have been explained by unusual melatonin secretion and circadian rhythms in some people with neurodevelopmental differences. But Foster remains cautious, pointing to a lack of randomised controlled trials that have been validated through repetition.

Still, it is easy to see melatonin's attraction. Recommended behavioural strategies for children experiencing poor sleep include setting consistent bedtime routines,

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MATTHEW HORWOOD/GETTY IMAGES

avoiding electronics before bed and encouraging them to fall asleep and stay asleep without parental help. Many families would argue that relying on these tactics alone is unrealistic – in which case, the mere possibility of increasing sleep duration by up to 68 minutes seems like a reward worth aiming for.

But what about the risks? The American Academy of Sleep Medicine (AASM) says that when taken in the short term, there are few reported severe effects in adults. However, common side effects in adults include headaches, dizziness, irritability, dry mouth, strange dreams and night sweats. Melatonin can also interfere with prescription medications. The AASM reports an association with a rise in depressive symptoms and caution is required for those with epilepsy or those taking the blood-thinning drug warfarin.

Standard prescribed doses of melatonin differ depending on where you live. In the UK, adults with insomnia can be prescribed 2 milligrams per night for up to 13 weeks. For jet lag, the dose is up to 6 milligrams per day for up to five days. Taken in the short term, for adults at least, it seems a safer bet than drugs like benzodiazepines and benzodiazepine receptor agonists (so-called Z-drugs) that are sometimes prescribed for insomnia, which can result in considerable adverse effects, including falls, lowered mood, confusion, cognitive impairment, dependence and withdrawal. The long-term safety of melatonin in adults remains untested.

Short-term use of melatonin in children also appears fairly safe: in 2014, researchers met in Rome to discuss the matter and concluded there was no evidence of serious adverse effects in children, although acknowledged this was based on limited trials. There have been concerns that long-term use could delay children's sexual development, possibly by disrupting the decline in night-time melatonin levels that occur at the onset of puberty. Indeed, some early studies suggested that melatonin use might delay puberty or cause infertility.

However, these studies were mainly carried out in cats, rats, mice and hamsters, rather than humans. Reassuringly, a 2021 study of 80 children and adolescents, most of whom were autistic, and who were given a nightly dose of up to 10 milligrams of melatonin for two years, showed there were no detrimental effects on children's growth and sexual development.

> **"It is unlikely that melatonin-rich foods have any physiological impact on sleep at all"**

SHUTTERSTOCK/ANGEL ALEXIS LUNA LARIOS

JEFFREY ISAAC GREENBERG 8+/ALAMY

Actual melatonin content can vary widely from what is advertised on the packet

What's in the box?

As with any supplement, you need to be careful where it is stored. Melatonin is the most frequently accidentally ingested substance among people under 19 in the US, with the annual number increasing by 530 per cent between 2012 and 2021. During this time, five children required mechanical ventilation and two died.

Finally, there is one factor you may want to consider before popping a nightly pill: it can be hard to know what is actually in the bottle. Melatonin for human use tends to be sourced

Melatonin is increasingly used by people who work night shifts to help them sleep in the day

from pigs or produced synthetically. It is basically indistinguishable from your body's version, says Lauren Erland at the University of the Fraser Valley in British Columbia, Canada. However, there are no requirements in Canada or the US for companies to test pills to confirm the melatonin content they are advertising.

In 2017, Erland and Praveen Saxena at the University of Guelph in Ontario, Canada, analysed 31 melatonin supplements from local grocery stories and pharmacies in Guelph. Melatonin content ranged from 83 per cent lower to 478 per cent higher than what was claimed on the bottle or packet. For 71 per cent of supplements, the amount didn't fall within a 10 per cent margin of what was promised. One chewable tablet for children contained 9 milligrams of melatonin, says Erland, rather than 1.5 milligrams.

These unexpectedly high levels aren't harmful to most people, she adds, but the risks rise in people taking medications that interact with melatonin and in people with health conditions that increase their susceptibility to the drug's side effects.

A quarter of the tested supplements also contained serotonin – a precursor of melatonin that is a much more strictly controlled substance. The amount was tiny and the researchers say it was unlikely to have significant health outcomes. They report that it may have come from plant extracts in some of the supplements, but its presence in supplements lacking these extracts is more difficult to explain.

So where does this leave us? The recent evidence for melatonin's poor results as a sleep aid for adults has led to a change of heart by some professional bodies, although recommendations by one often contradict those by another. The AASM says melatonin shouldn't be used to treat chronic insomnia, which is where insomnia occurs at least three times a week for three months, in adults. But it does acknowledge its utility in treating jet lag if taken at an "appropriate time". Unfortunately, it doesn't specify what an appropriate time actually is, although in associated information for patients, it states that doctors recommend taking melatonin before the time you want to go to bed, beginning before your trip and continuing for a few days after your arrival. This contradicts advice from the UK's National Institute for Health and Care Excellence, which says melatonin should be taken for up to five days, with the first dose taken at bedtime after you have arrived at your destination.

> "Melatonin isn't recommended for insomnia because of low efficacy"

The European Sleep Research Society says "melatonin is not generally recommended for the treatment of insomnia because of low efficacy". The British Association for Psychopharmacology, meanwhile, says melatonin may be useful in delayed sleep-wake phase disorder, which includes jet lag, as well as a difficulty falling asleep at the desired time and struggles with waking at the required time, but acknowledges that behavioural regimes can also be used.

If you are keen to avoid drugs altogether, you might have considered consuming melatonin-rich food and drinks to help promote better sleep. Walnuts, oranges, grapes, eggs, dairy and wine have all been touted as helping us sleep. Sadly, David Kennaway at the University of Adelaide, Australia, says this is wishful thinking. His review of several studies analysing the effect of melatonin-rich food on sleep shows that most of them were poorly conducted and uncritical in their evaluation.

Kennaway concludes that it is unlikely that the amount of melatonin in so-called melatonin-rich foods will have any physiological impact. Instead of changing your diet, most organisations recommend cognitive behavioural therapy as a first-line treatment for insomnia, and there are many new studies that show promising results in this area.

Nevertheless, when it comes to poor sleep, desperate times call for desperate measures, and even Foster has turned to the hormone of darkness when he was flying between the UK and Australia a lot. It didn't work for him, yet he continued to take it – just in case. Only when it began to lower his mood – a rare side effect with an unknown mechanism – did he stop. Indeed, the prospect of a good night's sleep is just too tantalising for many, and the popularity of melatonin supplements shows no signs of waning, despite a lack of evidence supporting their worth for most. Across the world, the supplements continue to emerge from bottles each evening, and so, for now, the Dracula hormone lives on. ▮

Jules Montague is an author, journalist and former consultant neurologist, based in London

The sounds of space

A growing number of astronomers are converting cosmic signals into sound to help discover the unexpected, finds **Ajay Peter Manuel**

IT SOUNDS like a firework, a bang followed by a crackle of faint sparkles. Then, a background hum builds. Soon, that is overtaken by what sounds like a crashing wave, followed by another and another, each louder than the one before. In between the waves, random notes beep.

This is the sound of a black hole. Specifically, a "black hole-star system" around 7800 light years from Earth called V404 Cygni. The firework is the sound of the black hole. The crashing waves are light echoes, bursts of energy that bounce off gas and dust in the vicinity. The random notes are individual stars.

This isn't what a black hole would sound like in reality. It is a soundscape created by NASA to represent data from telescopes. Using sound this way, known as sonification, isn't new. For decades, it has mostly been used for public outreach or by a handful of astronomers who are blind or partially sighted.

But in recent years, more and more astronomers are realising the benefits of "listening" to the universe. It enables them to sift through swathes of data they would otherwise struggle to analyse and even pick out signals they might have missed. "Our auditory system can often discern patterns and extract meaning, even when our visual system is not able to do so," says Bruce Walker at the Georgia Institute of Technology. Now, a movement is under way to transform into sound the influx of data from observatories around the world and beyond. The hope is this will offer an extraordinary new take on the universe and lead to more discoveries.

The first astronomical findings made this way were accidental. In 1932, US physicist and radio engineer Karl Guthe Jansky was tasked with identifying sources of static in overseas radio communications. Using a rotating antenna that he built and nicknamed "Jansky's Merry-go-round", he could hear a persistent hiss throughout the day. After ruling out all sorts of other possible explanations, Jansky eventually discovered the troubling hiss was, in fact, the result of radio waves coming from the centre of the Milky Way. This was the birth of radio astronomy.

Lightning on Saturn

It wasn't until the 1960s that astronomers began listening to their data on purpose. And it was Donald Gurnett at the University of Iowa who pioneered the technique. When data came back from the Voyager 1 mission as it flew past Io, a moon of Jupiter, in 1979, Gurnett listened to the signals and identified low-frequency radio waves. In the 1980s, Gurnett and his colleagues used sonification to identify problems affecting the Voyager 2 mission as it traversed the rings of Saturn. When they converted signals from the craft's radio and plasma wave science instrument into an audio representation, they heard sounds that they described as "resembling a hailstorm". This led to the discovery that electromagnetically charged micrometeoroids the size of grains of dust were bombarding the probe.

Later, in 2004, Gurnett took data from the Cassini mission and turned it into sound to discover lightning on Saturn as well as radiation emitted by electrons in the planet's auroral zones. The popping and crackling of the lightning sound like the kind of noise you might hear if you listen to a radio during a thunderstorm on Earth.

Gurnett, who died in January 2022, was keenly aware of the benefits of listening to, rather than just looking at data. For one, sonification creates a new way to digest complex data. Say you want to understand the way a galaxy gives off a certain frequency of light. You are trying to work out how that is related to that galaxy's age, mass and other properties, like the way it moves or the gas it gives off. This is more than the four dimensions (height, width, depth and time) that can be displayed visually. If we use sound, we can portray up to 12 dimensions at once, says Anita Zanella at the University of Cambridge. "Sound has up to 12

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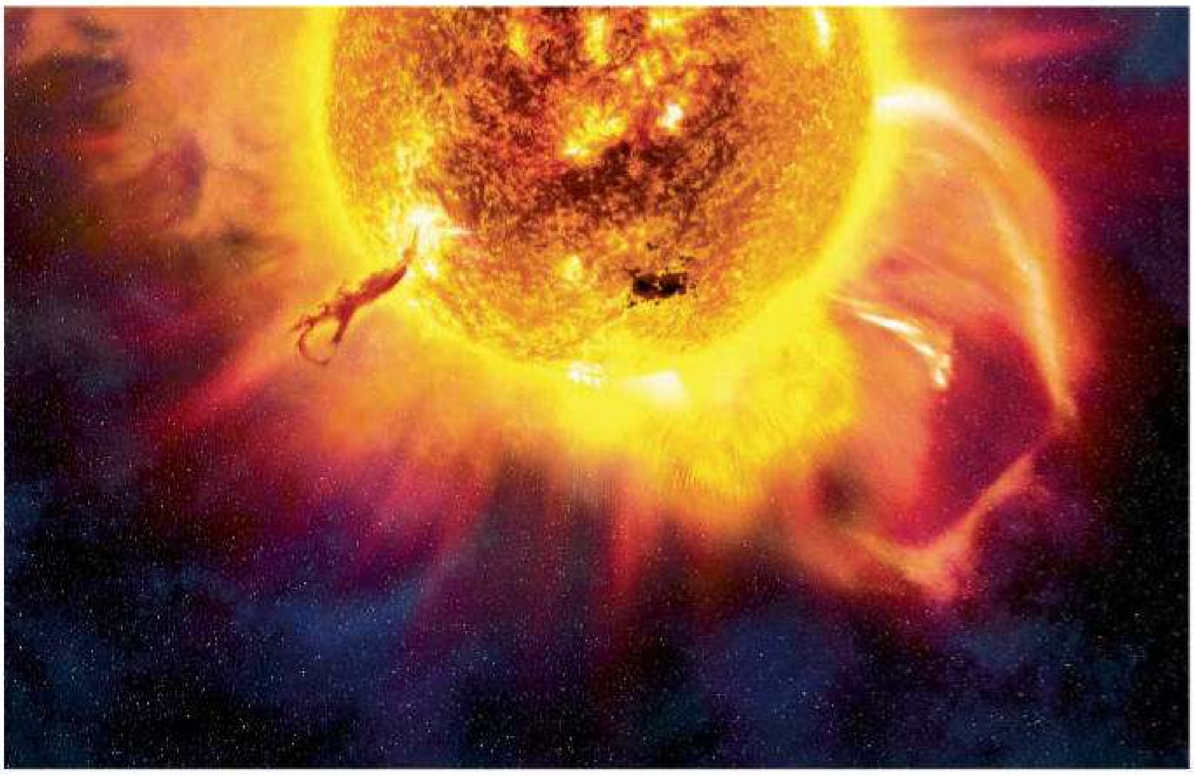
HARDZIEJ STUDIO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NASA/JPL-CALTECH

Sonification has been used to study solar flares (above), to identify problems on the Voyager 2 mission (middle images) and to research gamma ray bursts (far right)

parameters that characterise it, including frequency, rhythm, spatialisation and so on."

A further benefit lies in the fact that we can focus on several sounds at the same time while filtering out unnecessary noise. This is the skill that helps us understand what our friends might be saying in the middle of a loud party, hence why it is dubbed the cocktail party effect.

That makes sonification a way to help pick out weak signals in noisy astronomical data. "A lot of [astronomical] research is about detecting faint signals from distant sources in space within a noisy background," says Zanella. Gravitational waves are a good example. Take, for instance, two black holes merging. In one piece of research, Zanella simulated the gravitational wave signal this merger would give off and inserted it into an actual dataset from the Laser Interferometer Gravitational-Wave Observatory, or LIGO. "Visually, you cannot distinguish the signal from the noise," she says, "but when you listen to the sonification, it is clearly distinguishable."

Someone else who knows all about the value of this technique is Wanda Díaz-Merced, an astronomer at the European Gravitational Observatory in Cascina, Italy. She was a teenager when she started to lose her eyesight. "I would look at my mother," she recalls, "and while I knew she was there and I could see everything else around her, I couldn't see her." As the years went by, her vision deteriorated until, at university studying physics, she faced the prospect of going blind. She thought she would have to quit.

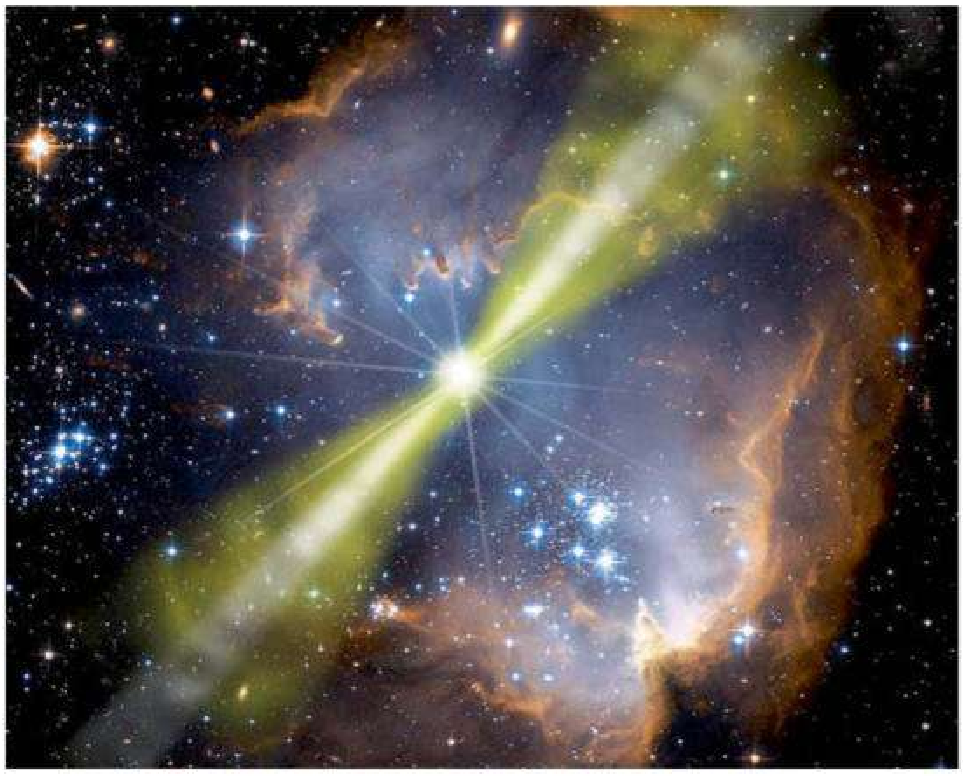
This all changed when a friend played Díaz-Merced the sonification of a coronal mass ejection, a giant expulsion of plasma from the sun. In that moment, she had an epiphany. With the help of colleagues, and a lot of time combing spreadsheets, Díaz-Merced began turning all her data into sounds. She has since used sonification to study gravitational waves, black holes and gamma ray bursts – the brightest displays of light since the big bang.

> **"She heard strange chirps, squeaks and rustles within the noisy data"**

On one occasion, Díaz-Merced was listening to the sounds of a gamma ray burst when she heard strange chirps, squeaks and rustles within the noisy data. The sounds reminded her of those of the solar wind. On the back of this, she and her collaborators discovered that the gamma ray bursts gave off energetically charged particles that are crucial to the formation of new stars. "We are used to listening to multiple sounds at the same time, separating signal from noise and determining how the various sounds are related – or not," says Walker. "Sonification can convey information about multiple sources or events or data streams, and listeners can process and make sense of it."

This is particularly important at the moment in a branch of astronomy that seeks out so-called transient phenomena. Also known as time-domain astronomy, it is the study of transient objects in the sky that change over relatively short timescales, for example the explosion of a dying star that only stays bright for a few weeks or the flash of a rapidly spinning neutron star seen for a matter of seconds. Many of the out-of-the-blue discoveries made in astronomy to date have been accidental detections of transient events and some people think transients are the best way to

NASA/JPL



NASA/SWIFT/MARY PAT HRYBYK-KEITH AND JOHN JONES

discover things we can't even imagine exist. For this reason, the Vera C. Rubin Observatory in Chile, which is due to start observations in 2023, will be scanning the entire southern sky every three nights for 10 years for the Legacy Survey of Space and Time (LSST) – designed specifically to look for these kinds of flashes. The observatory's newest project, Rubin Rhapsodies, will offer anyone full access to LSST data represented as audio in an effort to expand access to its archive.

In Australia, a project called Deeper, Wider, Faster, which coordinates more than 30 telescope facilities worldwide and in space, has already started using sonification for monitoring transient astronomical phenomena. This has identified thousands of such phenomena within our own galaxy, including dozens of M-dwarf flares, which are stars that experience unpredictable and sudden increases in brightness over timescales of seconds to minutes, and type 1a supernovae, stellar explosions involving binary star systems.

You might wonder, given the complex nature of the datasets astronomers obtain from our telescopes, why artificial intelligence and machine-learning systems aren't being used instead of sonification. However, automated analysis is generally based on known behaviour and phenomena. In other words, this kind of AI is good at picking out specific signals it is designed to look for, but not so good at noticing something different and saying "that's interesting". At least, not yet.

But the universe is full of phenomena we are yet to completely understand, and a large part of astronomy – particularly that conducted by telescopes like the Vera C. Rubin Observatory – involves scanning the sky searching for something new. For noisy and multidimensional datasets, sonification provides a chance for human input to help identify interesting features, as well as discern the significance of outliers and anomalies, train machine-learning software and decide what is relevant in the data. AI systems still have a way to go in emulating these features of human cognition, especially when confronted by uncertainty.

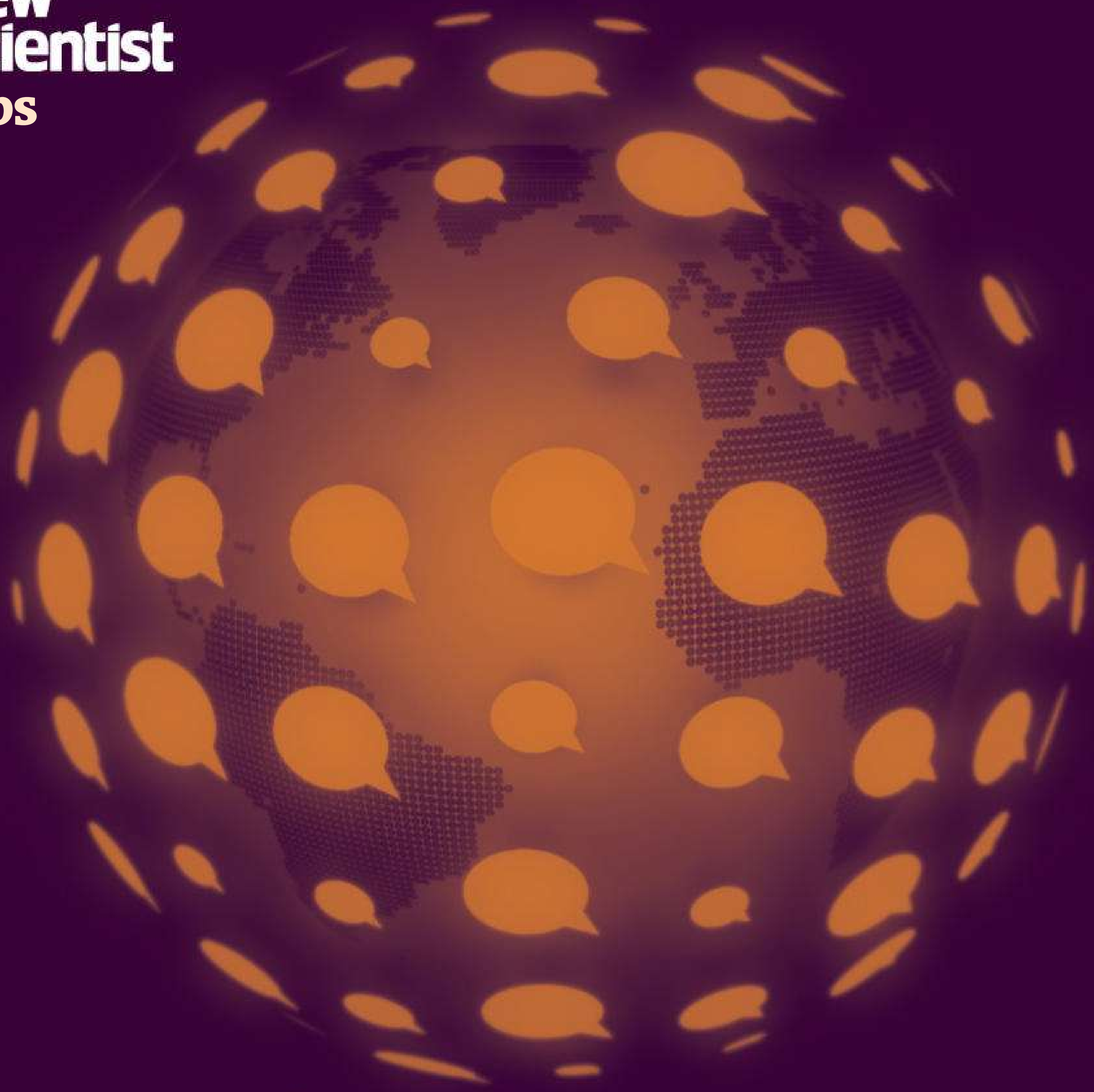
One stumbling block is that there are multiple ways to turn astronomical data into sound. Because of its piecemeal history, astronomers who use sonification today mostly do so using techniques passed down by colleagues or that they have developed themselves. These methods often aren't rigorously tested for their efficacy and are neither published nor peer-reviewed, further limiting knowledge exchange and increasing the risk of reinventing the wheel many times.

To tackle this, Zanella has collaborated with the psychology department at the University of Padova in Italy to develop the first joint PhD in astronomy and psychoacoustics, which is the science of how we perceive sound. The programme began at Padova this October, with the aim of finding the best ways to sonify astronomical datasets and establish standardised methods, so that, one day, these will be the standard techniques available to everyone.

For Díaz-Merced, this all adds up to an exciting step forwards in astronomy. More telescopes turning their data into sound improves the accessibility for people who are blind or visually impaired, and means fewer people will face the decision she was confronted with – whether or not to continue studying physics.

Beyond this, she is happy to see a technique she has used for so long start to be taken up by the wider community. "There is still a lot to be done," she says. Many scientists are yet to accept that there are other ways to analyse information, but she remains hopeful. "There is a universe of possibilities and I'm really excited about it." ▮

Ajay Peter Manuel is a science writer based in Calgary, Canada



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2023
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New Scientist Jobs, in association with SRG, is conducting its Global Salary Survey 2023 (STEM) to provide you with the latest insights.

If you work in STEM, we would love your thoughts and feedback. To find out more and complete the survey, go to

newscientist.com/salarysurvey

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The science of cooking

Sugar for my honey

To make honeycomb, or cinder toffee, you start by heating sugar and water. Then you need to avoid crystallisation, says **Sam Wong**

Sam Wong is assistant news editor and self-appointed chief gourmand at *New Scientist*. Follow him @samwong1

What you need

200 g table sugar
150 g honey or golden syrup
50 ml water
1.5 tsp bicarbonate of soda

The science of cooking appears every four weeks. Share your cooking successes with us on Twitter and Instagram @newscientist, using the hashtag #NewScientistCooking

Next week

Stargazing at home

HONEYCOMB, or cinder toffee, is simple to make, but is a great example of the complex science involved in transforming sugar into confectionery.

The process begins by heating sugar and water. While pure water boils at 100°C (212°F), the boiling point of a sugar solution is higher. As the solution boils, water evaporates, but the sugar remains, increasing the concentration and raising the boiling point further. At 170°C (338°F), the sugar starts to caramelise: the molecules break apart and recombine, turning it brown and producing delicious flavour molecules.

By measuring the temperature of a boiling sugar solution, you can tell how much water is left, indicating what texture the sugar will have when it cools. For a hard toffee, like honeycomb, you want to get to 150°C (300°F). Without a thermometer, you can keep track by dropping a small amount of hot sugar solution into cold water. At 110°C (230°F), it will form soft threads; at 125°C (260°F), a hard ball. At 150°C, it forms hard threads that crack easily. The boiling point rises more rapidly as the sugar gets more concentrated, so watch carefully to avoid burning it.

With less water than when it started, the hot sugar solution is supersaturated, containing more sugar now than can remain dissolved within it. As it cools, the sugar molecules will tend to bond together into orderly crystal structures. To make hard and brittle confectionery, you want to avoid this, as it makes the texture grainy. One way is to cool the syrup quickly so the sugar molecules can't arrange themselves into crystals – instead, they form a disorganised mass with a hard, smooth texture like glass.

JUSTIN ALLFREE/ISTOCKPHOTO/GETTY IMAGES

Other ingredients can prevent crystallisation. Table sugar, also known as sucrose, is made of glucose and fructose bonded together. If a sucrose solution also contains unbonded glucose and fructose – called invert sugars – they will get in the way of sucrose molecules and stop crystals from growing. Honey and golden syrup are sources of invert sugars. Also, acid, such as lemon juice, breaks down sucrose into glucose and fructose, so adding it is another way to supply invert sugars.

To make honeycomb, line a baking tin with greaseproof paper. Place sugar, honey and water in a saucepan over medium-high heat and stir with a wooden spoon. When it reaches 150°C, add and mix in the bicarbonate of soda.

The heat causes the sodium bicarbonate to break down to produce sodium carbonate and carbon dioxide. The bubbles of CO_2 get trapped in the candy as it cools, creating a light texture. Sodium bicarbonate is also alkaline, which lets caramelisation occur at a lower temperature.

Pour the syrup into the tin and leave it to cool before breaking it into chunks. Store in an airtight container, as the sugar may absorb moisture from the air. ▮

These articles are posted each week at newscientist.com/maker

Swansea University
Prifysgol Abertawe

Computational Foundry
Ffowndri Gyfrifiadol

EPSRC Centre for Doctoral Training in Enhancing Human Interactions and Collaborations with Data and Intelligence Driven Systems – Call for Applications for 4-year Funded research studentships.

"Permacrisis" is the Collin's Dictionary word of 2022, reflecting the very real global concerns we have all experienced. It is easy to despair but at Swansea University we are working to use AI and data-driven systems to bring hope and transformation. We do this by focussing on the most important technology of all: people. We are now looking for the next group of PhD researchers to join our Centre, people who are committed to changing the world via world-class research that focuses on amplifying human capabilities using data driven and intelligence enabled systems. The programme spans 4-years and includes an integrated Masters.

Working alongside a rich and diverse set of partners – including Facebook, Siemens, Tata, NHS and Google – successful candidates will use a people-first approach to drive exciting, adventurous and impactful socio-technical breakthroughs.

The Centre is housed in the state-of-the art Computational Foundry at Swansea University. Members of the Centre will be nurtured by multi-disciplinary supervisors with globally leading research agendas in Computer Science, Mathematics, Engineering, Management, Medicine and Social Care and Law. If successful, you'll be part of a community of 40+ PhD researchers, each supporting and learning from each other.

Candidates should have an aptitude and ability in computational thinking and methods including the ability to write software or enthusiasm to learn how to do so. While such aptitude might be evidenced by a degree in Computer Science or Engineering, we are building a community that aspires to have a high degree of diversity of perspective. So, if you have a background in Arts and Humanities; Social Sciences; Management for instance, please be encouraged to apply.

For future AI and big data technologies to serve society and the economy effectively, they must be created and critiqued by a diverse and wide set of perspectives as possible: we welcome applications from anyone who feels they can help in the Centre's mission.

This year, we have 12 fully funded places (fees plus stipend set at the UKRI rate).
Places are also available for those in receipt of four-year external funding.
We welcome candidates from anywhere in the world.

To discuss your application, please contact Professor Matt Jones (Director-Enhance-CDT@swansea.ac.uk)

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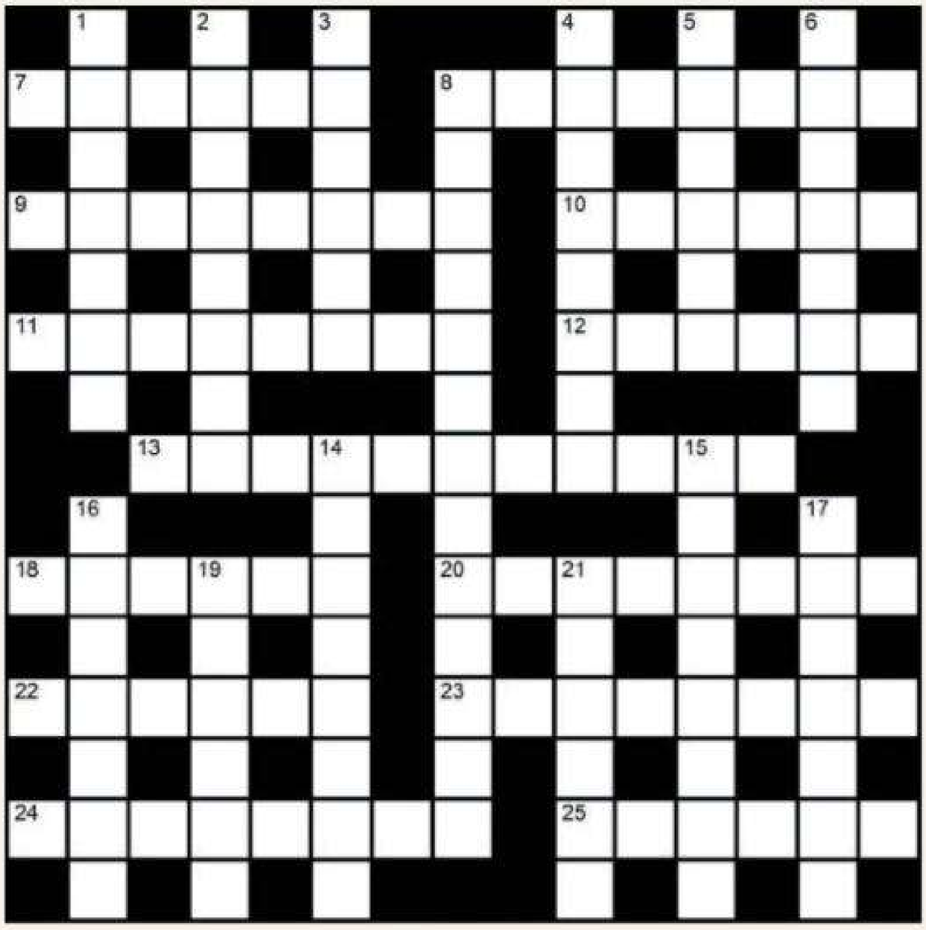
Quick crossword #123 *Set by Richard Smyth*



Scribble zone

Answers and the next cryptic crossword next week

ACROSS

7 Wake up (4,2)

8 Tl (8)

9 ___ veins, enlarged, twisted blood vessels (8)

10 Cerumen (6)

11 Brown owl of New Zealand (8)

12 O (6)

13 1981 fantasy sci-fi film directed by Terry Gilliam (4,7)

18 Shrub in the mint family, used in herbal medicine (6)

20 Soman or sarin, perhaps, when evaporated (5,3)

22 Neutrino experiment; moon crater (6)

23 Type of fuel plant (8)

24 Rodent, *Rattus norvegicus* (5,3)

25 Plant also called rushfoil (6)

DOWN

1 Nine-sided figure (7)

2 Disease caused by thiamine deficiency (8)

3 Pygmy chimpanzee (6)

4 Amphibian, notoriously invasive in Australia (4,4)

5 Optical disc format launched in 2006 (3-3)

6 Changes into a chrysalis (7)

8 Long-running BBC astronomy series (3,3,2,5)

14 Quantity of light allowed to reach a photographic film (8)

15 Hollow-boned carnivorous dinosaur (8)

16 Selsyn (7)

17 Type of mechanical digger (7)

19 Threaded fasteners (6)

21 Cut out surgically (6)

Our crosswords are now solvable online
newscientist.com/crosswords

Quick quiz #182

1 Extant odd-toed ungulates can be divided into three families: Equidae, Rhinocerotidae and what else?

2 Does the hormone leptin increase or decrease appetite?

3 In astronomy, what name is given to the abundance of elements in an object that are heavier than hydrogen and helium?

4 Plants of the genus *Ilex* are better known by what name?

5 On the geological timescale, what era was the longest in Earth's history?

Answers on page 55

Puzzle

set by Mary Ellis

#202 The dating game

Every day I play a little game with the date, to keep my mind sharp. The rules are very simple: you take the three numbers that express the date in its simplest form and combine them mathematically in various ways to try to make the numbers 1 to 10.

You are allowed to use the four operations of addition, subtraction, multiplication and division, as well as brackets, square roots and powers. You may use any of these as many times as you want, but you can only use each number in the date once and you have to use all three numbers each time.

My favourite date of 2022 was 16 September (expressed as 16/9/22) because I found a way to make every number from 1 to 10 following those rules, though it took me a while and I used square roots a lot. For example, I found "1" this way: $\sqrt{22 + \sqrt{9}} - \sqrt{16} = 1$.

Can you find a way to get the numbers 2 to 10 with that date?

Solution next week

Origin of the bang

In which direction in the sky did the big bang take place 13.8 billion years ago?

Luce Gilmore
Cambridge, UK
The big bang was the origin of space and time (as well as matter and energy), hence it happened everywhere.

Mike Follows
Sutton Coldfield, West Midlands, UK
The universe doesn't have a centre we can point towards. This is because the big bang wasn't a conventional explosion. If it were, you would be able to track the debris back to its origin and to a point in the sky. Instead, the big bang was the instant that both time and space were created. The space between galaxies is increasing with time.

The universe is isotropic and homogeneous, which means that it looks pretty much the same in all directions and reasonably sized samples appear identical. From our perspective, it appears as if the universe is expanding away from us. Aliens in other galaxies would also have the same perception: that the universe is expanding away from them in all directions, as if they are at the centre.

> **"If the big bang had been a conventional explosion, you could track the debris back to its origin and to a point in the sky"**

Of course, we can't both be correct. Instead, we are all probably wrong and the universe probably doesn't have a centre.

Stan Williams
Sevenoaks, Kent, UK
The abstract ideas that cosmology raises are often very difficult to intuit.

The question of where the big bang took place is inherent in the cosmological principle, which states that the cosmos, at least on intergalactic scales, is uniform in all directions. This implies that there is no special place in the cosmos. Everything is relative to where you are, which, of course, is the starting point for Albert Einstein's great theories.

Many years ago, I discovered a lovely way to think about this inscribed on a wall inside a church in the Dee valley in Aberdeenshire, UK. The message said: "The Universe is a Circle whose Circumference is Nowhere and whose Centre is Everywhere".

So the answer to the question is that the big bang happened in whichever direction you care to look. And you will never find its boundary.

Herman D'Hondt
Sydney, Australia
The big bang took place everywhere in the universe – it was the universe. Hence, regardless of where you point, you always point in the direction of the big bang. The cosmic microwave background radiation, released when the universe was 380,000 years old, looks the same in every direction.

Imagine you are an ant living on the surface of a huge balloon. For the ant, the surface is its entire universe. The inside or outside of the balloon can't be observed. Now, imagine the balloon expanding. For the ant, there is no direction from which the expansion started, it is happening everywhere, in all directions. It is a bit like standing at the South Pole and trying to point in the direction of north. At the South Pole, all directions are north.

KEVIN SCHAFER/THE IMAGE BANK/GETTY IMAGES

Why are far fewer mammal species than bird species monogamous?

This week's new questions

Divided loyalty **Why is it that less than 5 per cent of mammal species are monogamous, compared with about 90 per cent of bird species?** ***Adrian Bowyer**, Foxham, Wiltshire, UK*

Balancing act **Having read several recent articles on nutrition and longevity, I wonder how many life-extending cups of tea I must drink to counter the life-shortening effect of eating a hotdog?** ***Ted Appleyard**, Waterloo, Ontario, Canada*

Want to send us a question or answer?
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Viral virtue

We hear about humans having and needing "good bacteria". Are there similarly "good viruses" in our bodies?

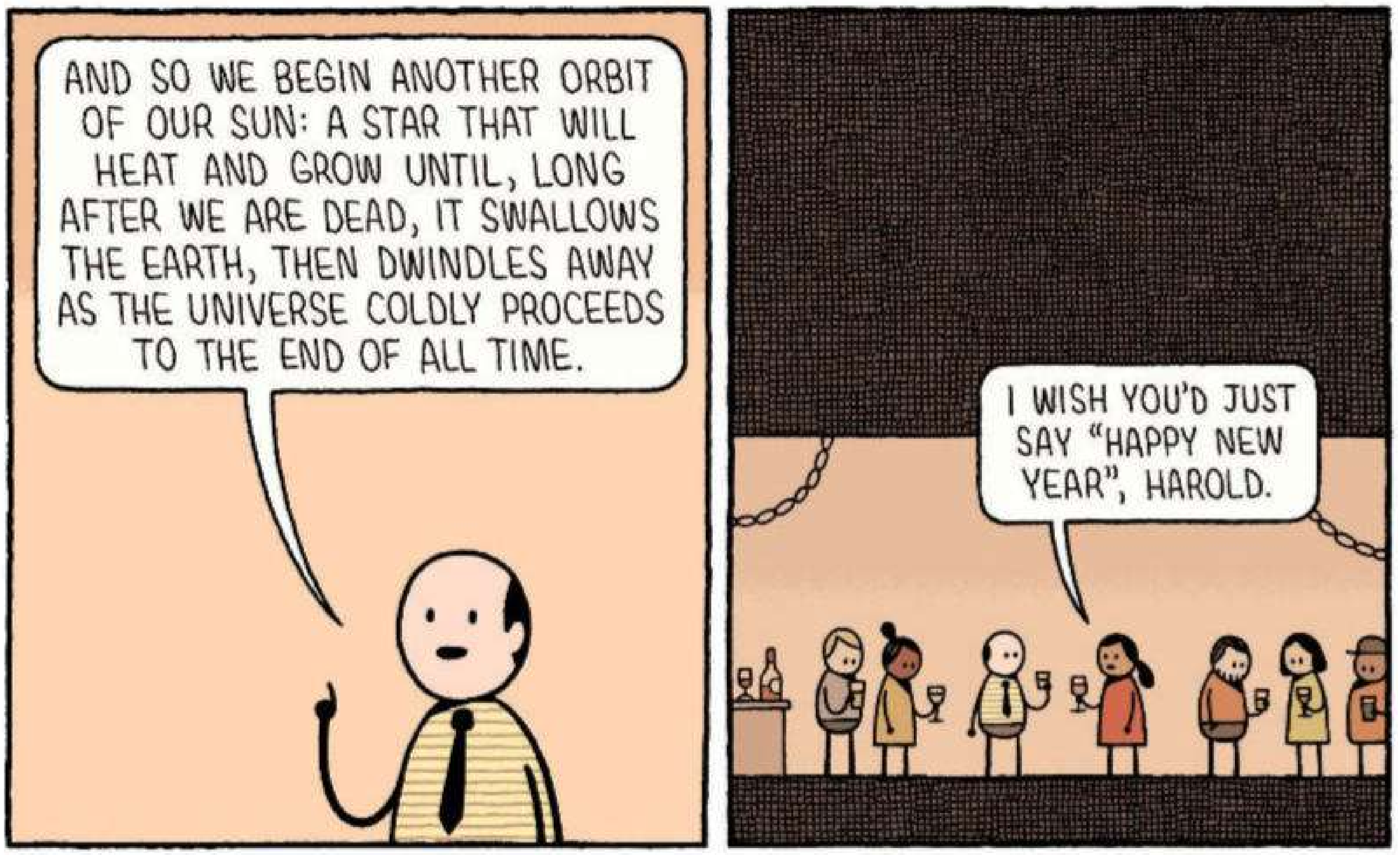
Robert Barrie
London, UK
Focusing specifically on the gut, there is indeed an equivalent of the bacteria that live there: the "gut virome". While not as widely appreciated as their bacterial accomplices, these viruses play a major role in balancing our gut microbiome, which is important in the prevention of diseases and bowel conditions. Indeed, there are more than 140,000 of these heroic microscopic agents that have taken up residence in our gut, helping us every day to maintain a healthy body. I am certainly not going to charge them rent!

Cheda Martis
Warrenton, Georgia, US
A healthy human gut (and skin etc.) has a plethora of bacteria, viruses and fungi that seem to work together to maintain each other at healthy levels. So far, though, most of our investigations have been into bacteria.

Our understanding of this ecosystem is so new that it is hard to define "good" and "bad" in an absolute way. For example, the bacterium *E. coli* occurs in healthy human guts and can have a healthy role, aiding digestion and iron uptake. But sometimes it can be pathogenic, causing gut illness and urinary tract infections, and it still isn't known what causes that change from "good" to "bad".

[Ed – We are beginning to discover that most parts of the body contain viruses that may be vital for our health. However, most of these

Tom Gauld
for New Scientist


AND SO WE BEGIN ANOTHER ORBIT OF OUR SUN: A STAR THAT WILL HEAT AND GROW UNTIL, LONG AFTER WE ARE DEAD, IT SWALLOWS THE EARTH, THEN DWINDLES AWAY AS THE UNIVERSE COLDLY PROCEEDS TO THE END OF ALL TIME.
I WISH YOU'D JUST SAY "HAPPY NEW YEAR", HAROLD.

viruses don't infect human cells, but bacteria. Known as bacteriophages, they play a vital role in controlling the diversity of gut bacteria and in defending the gut lining. Mouths seems to be a viral hotbed too. Each of us has a highly distinct and stable oral virome. Even our blood, once thought to be sterile, has a virome. Efforts are now underway to create atlases of all the viruses living in us.]

Pipe line

Aiming a hosepipe, intuition told me a 45-degree angle would maximise the distance travelled by the water, as it would for a projectile. But when I did this, the water actually went a shorter distance. Why? (continued)

Nick Canning
Coleraine, County Londonderry, UK
In previous responses to this question, the large deviations from 45 degrees for the optimum launch angle for maximum range of a garden hose were wrongly attributed to the effect of air resistance (3 September).

> **"There are more than 140,000 viruses that reside in our gut, helping us every day to maintain a healthy body"**

Such deviations are predicted, without air resistance, when projectiles are launched from a height above ground level. If the hose is at shoulder height (around 1.5 metres, say) and the initial water velocity is 1 metre per second, then, according to my calculations, the optimal angle should be 10.2 degrees, not 45 degrees. Effects of air resistance cause a less than 5 per cent reduction of these predicted optimum launch angles.

Chris Daniel
Colwyn Bay, Conwy, UK
The distance travelled by a stream of water from a hose depends on the flow rate, the angle of the nozzle and its height from the ground. When the hose is held well above ground level, the water will travel further when the hose is angled at less than 45 degrees, as the questioner observed.

Ignoring any air resistance, a jet of water from a hose will follow a parabolic curve. When the hose is held at ground level, water will travel the greatest horizontal distance when the nozzle is angled upwards at 45 degrees. As the arc of water rises from this starting point, its slope decreases from the initial angle – 45 degrees in this case – to zero as it reaches its peak then continues to decrease as it descends until it hits the ground at minus 45 degrees.

A gardener would normally hold the hose at some convenient height above the ground. This can be thought of as the hose being positioned further up and along the imaginary rising part of a parabola that starts with an angle of 45 degrees from ground level behind the gardener. The hose therefore has to be angled at less than 45 degrees to be aligned with the parabola's decreasing slope at this position to ensure that the jet of water travels the furthest possible distance. ▮

Answers

Quick quiz #182
Answers

1 Tapiridae
2 Decrease
3 Metallicity
4 Holly
5 The Palaeoproterozoic era, which spanned 900 million years, from 2.5 billion years ago until 1.6 billion years ago

---

Cryptic crossword #99 *Answers*

Dendrochronology is the science of analysing tree rings, to date and interpret past events. Our lonely dendrochronologist is making a dating app, as given by the starred solutions below. Annular (ring) answers overlap to give CEDAR, BEECH, LARCH, CHESTNUT, ASPEN and WILLOW, as shown in bold below. Protruding letters from the 7-letter radial answers give a word that is both the name of a dating app and a term for flammable material: Tinder. Note that (rev.) denotes radial answers written outwards.

ANNULAR 1 Spoke; Dens; Di**CE**; **DAR**win; Docs; Spend, **19** Alas; Seen; Retool; *App; Ado**BE**; **ECH**oed, **20** Kir; So**LAR**; **CH**ill; Wriggle; Rug; Troll, **21** Zinc; Tied; Ri**CHEST**; **NUT**rient; Ape; Negev, **22** Nepalese; Canv**AS**; **PEN**sion; Elation, **23** Raw egg; Need; Turf; Roan; T**WILL**; **OW**lish

RADIAL 1 Solder, **2** Peers at, **3** Weirdo (rev.), **4** Gargle (rev.), **5** *Dating, **6** Inverse (rev.), **7** Nestles (rev.), **8** Dialed (rev.), **9** Inkpot, **10** Werner, **11** Itself, **12** Dragoon (rev.), **13** Olivia, **14** Calzone, **15** Splint, **16** Parcel, **17** Riptide (rev.), **18** Saigon (rev.)

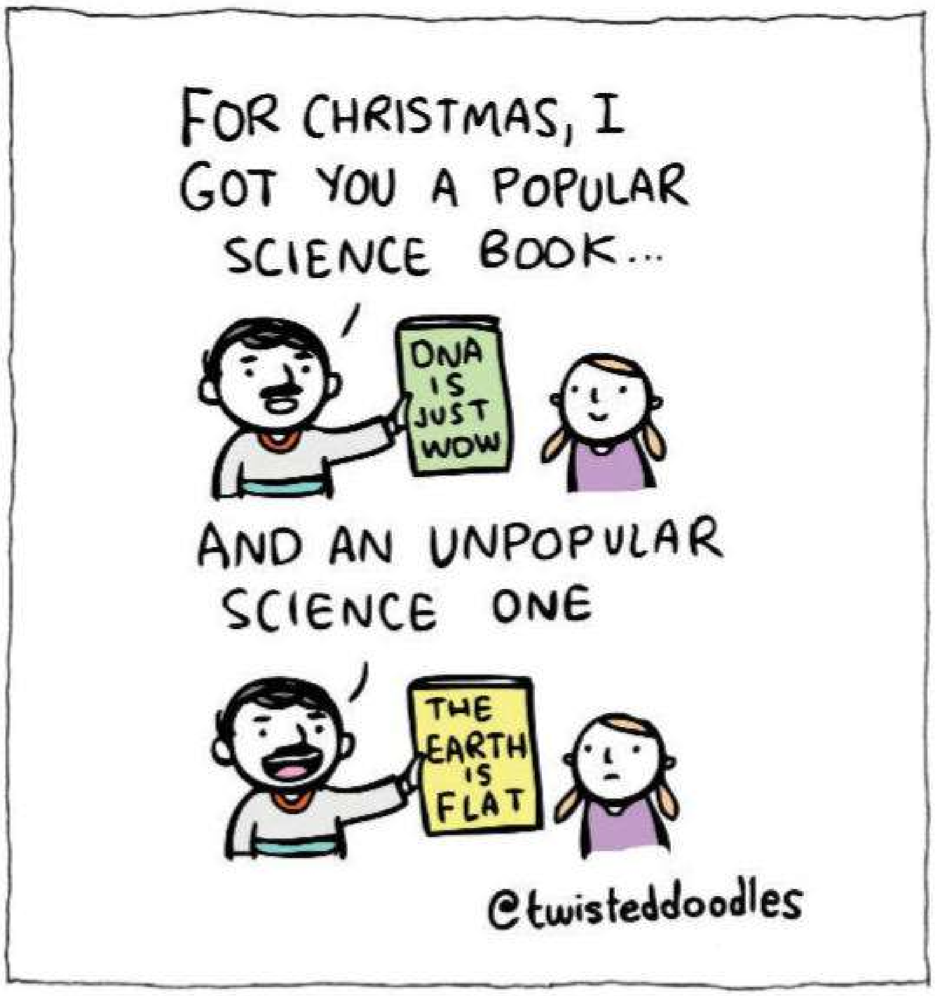
Double jeopardy

One approach to solving a tough problem is to tackle the most extreme version of it you can imagine. Find a solution to that, and the simpler variations become easy. Jane Ridley assesses a tough legal problem in an Insider.com article with an extremely long headline: "Identical college twins were accused of cheating in an exam by signaling. They won $1.5 million in damages after a jury decided they hadn't cheated because their minds were connected".

This kind of twins paradox becomes more consequential – and more extreme – if we up the level of the allegation. Let's make it murder. And conjoined twins. That exact combination got six pages of analysis in the *Alternative Law Journal* in 2017. In it, Colleen Davis at Griffith University in Australia navigated the complexities in a paper entitled "Complicity, Crime and Conjoined Twins".

"If one twin has committed a murder," Davis asks, "how can the guilty twin be punished without, at the same time, the innocent twin being unjustly punished as well?" The obvious methods, including "separate the twins and then execute or incarcerate the guilty one", have drawbacks, to say the least. Davis concludes that the problem brings "challenges that the law is ill equipped to deal with".

Twisteddoodles *for New Scientist*


FOR CHRISTMAS, I GOT YOU A POPULAR SCIENCE BOOK...
DNA IS JUST WOW
AND AN UNPOPULAR SCIENCE ONE
THE EARTH IS FLAT
@twisteddoodles

Got a story for Feedback?

Send it to feedback@newscientist.com or New Scientist, Northcliffe House, 2 Derry Street, London W8 5TT

Consideration of items sent in the post will be delayed

Out of the woodwork

London-based reader Neha Obhrai writes in: "During the renovation of our flat in Marylebone we found a sealed cupboard, and on opening it up to secure some utility storage found some very old *The New Scientist* catalogues."

Obhrai supplied photos that show the now-unsealed wooden cupboard and some of the magazines that, like pharaohs entombed in the Egyptian pyramids for a static journey towards forever, had lain for a long time concealed within. This includes a copy of the inaugural, 22 November 1956 issue (pictured).

Digging into our own archives, Feedback has found this first issue contains an article showing off the hopeful heights attained by astronomers. Under the headline "OUR NEIGHBOUR MARS", Professor Zdenek Kopal at the University of Manchester, UK, asserts that "three-quarters of its surface is a dusty Sahara. But on the remainder are signs of vegetation — and even animals may long ago have existed there".

Elsewhere, a letter signed "T. T. G." pleads: "Here is the dilemma: on the one hand we must, to save this country from ruin, press strenuously for more applied science; on the other hand we must restrain the engineers from driving us and our children mad."

Entombed in an old cupboard: The first ever *New Scientist*

Another, from an "E. St. John-Smithers", vents about scientists: "Their continual claims to be heard on general matters, to receive ever-increasing support from public funds, to have privileges at work denied to lesser mortals, are beginning to annoy the non-scientist... What we need is a forum to expose this bogus, not one that encourages it."

The 19 June 1958 magazine, also found by Obhrai, has an article by Dr. Norman E. Hickin, Technical Director of Woodworm & Dry Rot Control, Ltd. One passage now reads like a challenge that maybe inspired somebody to experimentally squirrel those magazines in that woodwork:

"There are certain well-known situations where Furniture beetle attacks originate, and these are all places where one would expect a little higher humidity than elsewhere in the house. The cupboard under the stairs and certain parts of the roof-void are examples of this... Woodworm eradication, however, is a job which a householder can carry out for himself if he conscientiously obeys some simple rules."

Decomposed alumni

Feedback's Ambiguously Titled Research Study of the Month (submissions for which are welcome) sets a standard, or a model, that higher education institutions can use as they strive to achieve total quality management and business excellence. The study is called "Developing a Decomposed Alumni Satisfaction Model for Higher Education Institutions". *Total Quality Management & Business Excellence* published it in 2016.

The decomposed alumni study cites a paper in *New Directions for Institutional Research*. Sensing the possible stink raised by a decomposed alumni study, one could detect morbid ambiguity in its title: "Assessing Alumni Outcomes".

Contemplation of the alumni outcomes study almost inevitably leads to a discussion of dead reckoning. This concerns an entirely different body of knowledge, exemplified by a study called "Pedestrian Dead Reckoning: A basis for personal positioning".

But that isn't the end of this journey backwards into the murk of ambiguity. The personal positioning study mentions, maybe ominously, a 2002 paper entitled: "Error Analysis of Step Length Estimation in Pedestrian Dead Reckoning". Where things lead, what steps one should or should not take, indeed whether one should even leave the house of a morning... these are all questions that, studies show, aren't easily solved. ■

Marc Abrahams

Inspiring gift for young readers

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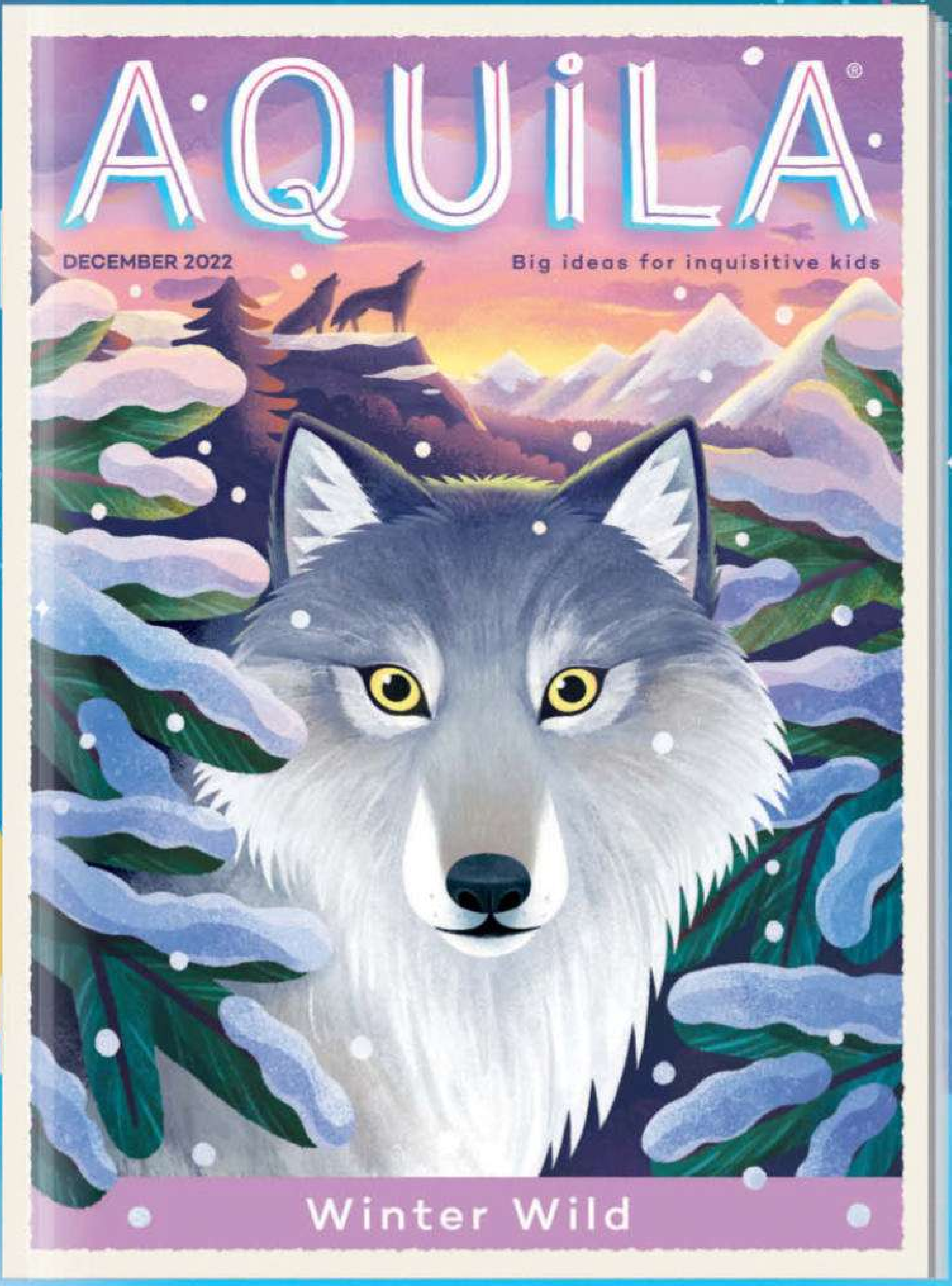

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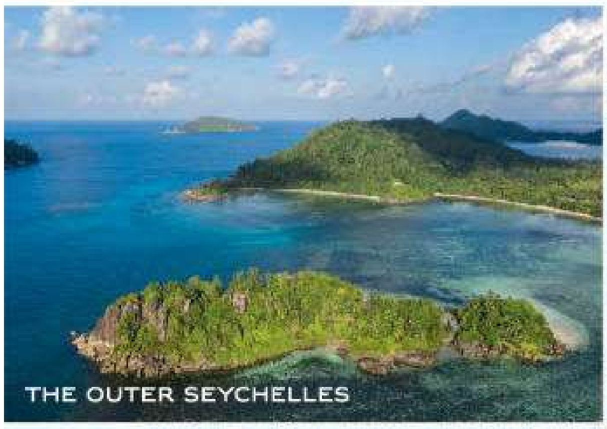

THE OUTER SEYCHELLES

AZORES ARCHIPELAGO, PORTUGAL

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SYLVIA EARLE EXPLORES
COCOS ISLAND, COSTA RICA

THERE ARE OVER 130
HOPE SPOTS GLOBALLY

SYLVIA EARLE WITH VOLUNTEERS,
THE OUTER SEYCHELLES

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Hope can now be spotted across all our planet's seas and oceans. Sites are made into aquatic havens by local communities, to safeguard the richness and diversity of the ecosystems they depend on. Sylvia Earle's invaluable experience as an explorer and marine biologist continues to help further their goal, through her organisation, Mission Blue. Together, they have created over 130 Hope Spots and counting. Carrying a message of hope for generations to come. It is that vision, that dedication to a perpetual planet, which we are proud to stand by. **For as long as it is needed.**

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